Improving the Quality of Book Printing Products through Six Sigma Approach that integrated with Experimental Design

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Abstract: This research applies the Six Sigma (DMAIC) approach which is integrated with experimental design at the process improvement stage. The research was conducted at a book printing company. Three dominant defects were found in the book printing process, namely uneven cutting results (44.29%), uneven colors (32.8%) and torn books (23.82%). The sigma value measured at initial conditions is 2.172. The research was carried out by following the Six Sigma DMAIC stages, and in stage I (improvement) experiments were carried out by changing the cutting speed process parameters. The experimental design uses a completely randomized design with the engine speeds to be tested in the experiment being 50 RPM, 60 RPM and 70 RPM. The number of replications in the experiment was 10 times at each level. The number of levels is 3, so the total number of trials is 30 experiments. The treatment stage selected based on the Student Newmann Keuls Test was a level 2 experiment with an independent variable of 60 RPM. The sigma value obtained in the post improvement condition was 2.58 σ, an increase in sigma of 0.408 compared to the initial condition. The percentage of post-improvement production defects is 4.62%.

Keywords: six sigma, experimental design, cutting speed, completely randomized design.

1. INTRODUCTION

Six Sigma method has been proven to be able to identify and eliminate defects, errors or failures in business processes or systems by focusing on process performance characteristics that are very important to customers (Snee, 2004). Six sigma method has been successfully applied in many large companies, but its application in smaller organizations is still less well documented (Jiju et.all, 2005). Various studies examining the application of six sigma in small and medium companies include Scheller et al, (2017), Kandil and Aziz (2017), and Swarnakar, Tiwari and Singh, (2020). Kandil and Aziz's (2017) research focuses on problems related to supply chains in small and medium enterprises in Egypt. The six sigma method is used to explore areas that need improvement and assess the impact of technology in improving company performance. Scheller et.al (2017) shows that Lean and Six Sigma are implemented separately in two different programs. Several aspects required to improve the integration of both approaches have been identified while considering each phase of DMAIC and the actual approach implemented by the company. Although some positive results have been achieved, there are many critical factors and failures that can affect the implementation of both approaches, such as employee training and changes in the organizational environment. Swarnakar, Tiwari and Singh (2020) conducted research with the aim of identifying, evaluating and developing a structured model that measures the interrelationship between critical failure factors (CFF) that influence the sustainable implementation of Lean Six sigma in manufacturing organizations. Six sigma research that uses experimental design at the Improve stage is still very limited. The research conducted examined the company's performance in reducing defective products through a series of DMAIC stages, and specifically carried out process improvements in stage I (improvement) by designing experiments. The research was conducted at PT X, a company engaged in the school textbook printing industry in the city of Bandung. Problems faced by book printing companies include overproduction caused by the unavailability of accurate information about the percentage of defective products in the post-print process. To anticipate the occurrence of defective products, PT X uses a policy of providing production tolerances higher than the demand in the employment contract with consumers. For example, in a particular contract the amount of consumer demand is 3 149 100 copies of books, but produced 3 486 680 copies of books. The disability rate is 7%, or about 244 067 copies of books. Although consumer demand can be met according to the contract, but defective products that are not sold are very high. The sigma value calculated by the six sigma method is still 2.17.

2. METHOD

The research was conducted in the school textbook printing industry using the Six Sigma approach, Pyzdek & Keller (2010), which includes the stages of define, measure, analyze, improve, and control. At the define stage , observation of the production process, analysis of production data and identification of types of defects that may occur in book printing products are carried out. The measure stage measures the number of defective products and the achievement of sigma values in conditions when research is carried out. The analyze phase identifies the root cause of the problem using pareto diagram tools, fishbone diagrams and failure mode effect analysis. At the improve stage, process improvement is carried out by conducting experiments through determining parameter settings on the cutting machine. The study used two types of data, namely primary data and secondary data. Primary data were obtained from interviews and observations of the Company's stakeholders, which include president directors, production directors, production supervisors and production operators. Observation is carried out by active observation where this research is carried out based on field conditions and researchers participate in the production process. The experimental design used to improve the cutting process is an experimental design with the Complete Randomized Design (RAL) method. Experiments were conducted to obtain an optimal parameter set up in reducing product defects in the 3-sided cutting section (treemar) in the TSK Binding Inline Machine.

3. RESULT AND DISCUSSION

3.1 Define

Define is the initial stage carried out in the DMAIC approach. At this stage, define and select the problems to be solved. Figure 1 is the process flow that occurs at PT. X, starting from the supplier to the hands of consumers using the SIPOC diagram (*supplier, input, process, output, customer*).

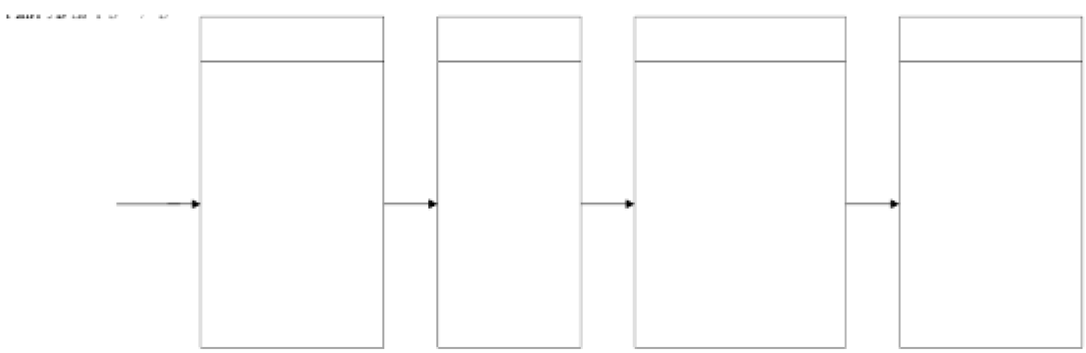

Figure 1. Diagram Supplier–Input– Process–Output-Control

PT. X has approximately 83 suppliers, ranging from suppliers of paper rolls, paper sheets, ink and others. At this stage explain the symptoms of problems observed at PT. X by using a cause effect diagram. The cause effect diagram can be seen in figure 2.

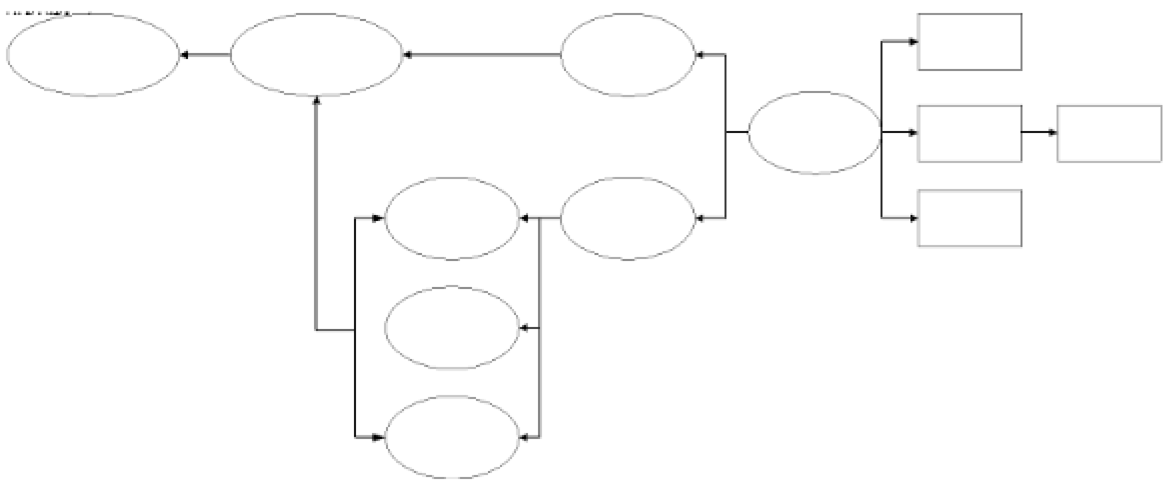

Figure 2. *Cause effect diagram*

3.2 Measure

Measure is the stage of measurement of problems that have been defined to be solved. At this stage, various data are measured, measuring process characteristics and capabilities. The data are presented in Table 1 to Table 5.

Table 1. Type and Quantity of Production

No.	Level	Class Level	Book Title	Oplagh Quantity (Units)
1	SD	1	Tema 1 - 8	423000
2	SD	2	Tema 1 – 8	420000
3	SD	3	Tema 1 – 8	642100
4	SD	4	Tema 1 – 8	548000
5	SD	5	Tema 1 – 8	471000
6	SD	6	Tema 1 – 8	645000
Total				3149100

PT. X initially experienced the phenomenon of overproduction, one of which was caused by the post-print process. The following are the production results for thematic books at the elementary school (SD) level for a certain year period.

Table 2. Thematic Book Production Results

No.	Level	Class Level	Book Title	Oplagh
				Quantit y (Units)
1	SD	1	Tema 1-8	484912
2	SD	2	Tema 1-8	474872
3	SD	3	Tema 1-8	697596
4	SD	4	Tema 1-8	596387
5	SD	5	Tema 1-8	531266
6	SD	6	Tema 1-8	701649
Total				348668 0

Table 3. Production-demand deviation

Level	Class Level	Book Title	Oplagh
			Quantity (Production Yield - Demand)
SD	1	Tema 1-8	61912
SD	2	Tema 1-8	54872
SD	3	Tema 1-8	55496
SD	4	Tema 1-8	48387
SD	5	Tema 1-8	60266
SD	6	Tema 1-8	55647
Total			337580

The difference in products is inventory produced by the company which will be stored in the warehouse and then sold at retail. The company suffered losses caused by the inventory. Estimated losses due to overproduction can be seen in table 4.

Table 4. Estimated Company Loss

Level	Class Level	Book Title	Difference (Eksemplar)	HET/Product	Total (Rupiah)
				ZONA 1	
SD	1	TEMA1- TEMA 8	61912	Rp 12,400.00	Rp 767,708,800.00
SD	2	TEMA1- TEMA 8	54872	Rp12,400.00	Rp 680,412,800.00
SD	3	TEMA1- TEMA 8	55496	Rp12,400.00	Rp 688,150,500.00
SD	4	TEMA1- TEMA 8	48387	Rp 12,400.00	Rp 599,998,800.00
SD	5	TEMA1- TEMA 8	60266	Rp 12,400.00	Rp 747,298,400.00
SD	6	TEMA1- TEMA 8	55647	Rp 12,400.00	Rp 692,502,800.00
Total					Rp 4,176,072,000.00

Besides inventory, there is a major problem experienced by the Inline *TSK Binding Machine* , namely production defects. Table 5 describes the number of defective products of thematic book production for the Primary School (SD) level in Theme 1 – Theme 8 in the TSK *Inline Binding Machine*.

Table 5. Number of defective products

No.	SD	Class Level	Book Title	Defective Products
				Total Amount
1	SD	1	TEMA 1 - TEMA 8	49,261
2	SD	2	TEMA 1 - TEMA 8	52,129
3	SD	3	TEMA 1 - TEMA 8	47,862
4	SD	4	TEMA 1 - TEMA 8	48,271
5	SD	5	TEMA 1 - TEMA 8	43,411
6	SD	6	TEMA 1 - TEMA 8	50,377
Total				291,311

Defective products are products produced in the production process with specifications that are not in accordance with the quality standards set by the company. The Company experiences losses caused by product defects so that if calculated losses based on defective products can be seen in table 6.

Tabel 6. Estimasi Kerugian Karena Produk Cacat

No.	Tingkat	Jenjang Kelas	Judul Buku	Produksi Cacat	HET/Produk	Total (Rupiah)
					ZONA 1	
1	SD	1	TEMA1- TEMA 8	49261	Rp 12,400.00	Rp 610,836,400.00
2	SD	2	TEMA1- TEMA 8	52129	Rp 12,400.00	Rp 646,399,600.00
3	SD	3	TEMA1- TEMA 8	47862	Rp 12,400.00	Rp 593,488,800.00
4	SD	4	TEMA1- TEMA 8	48271	Rp 12,400.00	Rp 598,560,400.00
5	SD	5	TEMA1- TEMA 8	43411	Rp 12,400.00	Rp 538,296,400.00
6	SD	6	TEMA1- TEMA 8	50377	Rp 12,400.00	Rp 624,674,800.00
Total						Rp 3,612,256,400.00

3.3 Analyze

The analysis stage is the stage to find a solution that can solve the problem based on the root cause that has been identified. The different types of manufacturing defects in PT X are described in Figure 3.

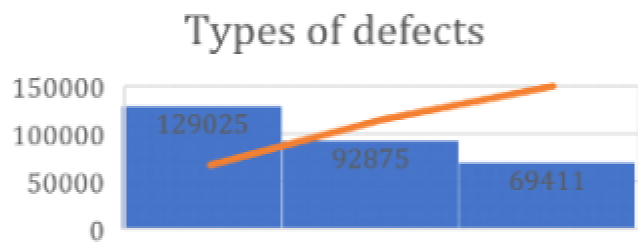

Figure 3. Different Types of Production Defects

Each type of defect is caused by various factors, which include human factors, *inline tsk binding machine* factors, 3-sided cutting method factors and environmental factors. The data stating the cause of the occurrence of manufacturing defects when sorted from the largest percentage of product defects is shown in Figure 3.

The deduction does not correspond to the percentage of disability of 44.291%

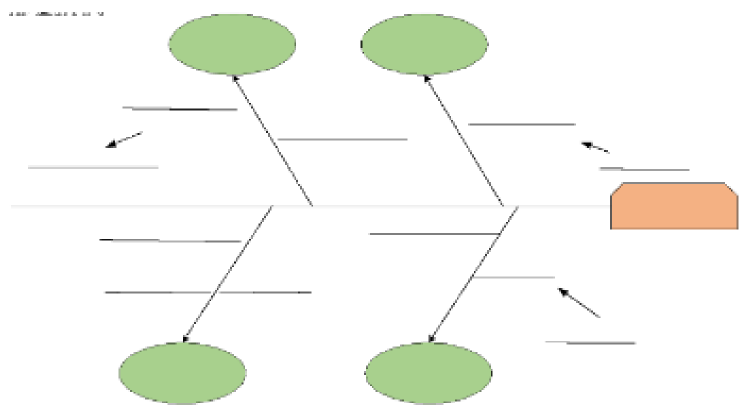

Figure 4. Product defects due to inappropriate cutting size

Inappropriate colors or uneven colors with a defect percentage of 31.884%

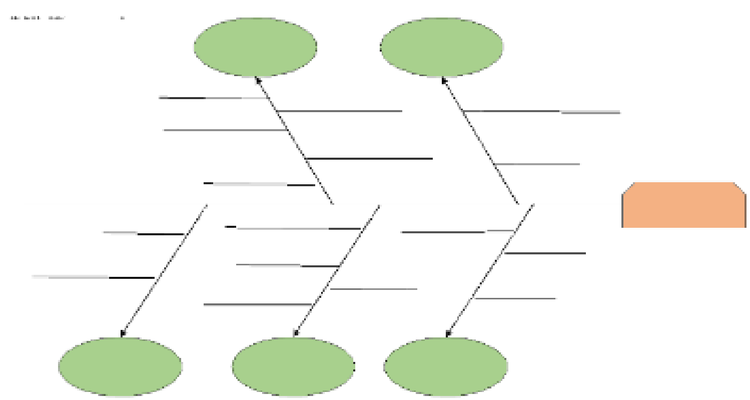

Figure 5. Product defects due to uneven color

Tearing with a manufacturing defect percentage of 23.827%

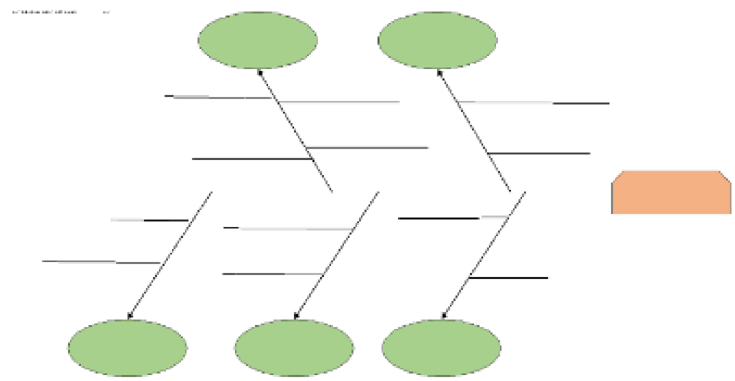

Figure 6. Product defects due to tearing

The measurement results show that the most dominant product defects are caused by *the Inline TSK Binding* Machine on the *treemar* (3-sided cutting). The dominant defect is thought to be caused by the engine speed (RPM) used is not optimal. The alleged cause of the dominant factor of disability is supported by the FMEA (*Failure Mode Effect Analysis*) diagram which shows this.

3.4 Improve

The *improvement* stage was carried out by designing experiments using the Complete Random Design (RAL) method on the *TSK Inline Binding* Machine of *the treemar* section (3-sided cutting). Factors to consider are engine speed (RPM) and the stack of books to be cut to minimize defective products. Settings to determine cutting parameters are obtained through primary data, both from the manual *book*, operator experience and policies from PT. X. In the *existing* state, the company uses three measures of engine speed (RPM), namely 55 RPM, 60 RPM, and 65 RPM. The stack of books will be cut in a *setting of* 4 – 7 books, depending on the thickness of the book. The small or large number of stacks of books is done based on the stack capacity required by the *inline binding TSK* Machine, which is 70 mm – 75 mm high. In this study, experiments were carried out by *setting a stack of* 5 books. Observations inform that the high speed of the machine will cause disruption to the *gathering* process for book filling, so that the book filling will be folded and when cut on 3 sides will experience product defects. The engine speed (RPM) is too slow will result in disruption of the queue when the cutting process is carried out on 3 sides of the *treemar*. The phenomenon that occurs in a low RPM state is the friction between 1 book and another book which causes the stack of books to become misaligned (experience a shift in books), so that the 3-sided cutting process becomes asymmetrical. Therefore, it is necessary to choose the right speed to minimize product defects. The engine speeds to be tested in the experiment are 50 RPM, 60 RPM and 70 RPM. The number of replications in an experiment is 10 experiments at each level. The number of levels is 3, so the total number of trials is 30 trials. The experimental results are shown in Table 7.

Table 7. Experimental data

Operating Parameters	Speed		
	Level 1	Level 2	Level 3
	50 RPM	60 RPM	70 RPM
Production Defects (in book copies)	1177	933	1284
	1199	1047	1259
	1303	1004	1357
	1259	1068	1308
	1314	1045	1368
	1259	938	1307
	1154	937	1526
	1307	936	1088
	1264	981	1303
	1283	1173	1324
Sum	12519	10062	13124
Many Observations	10	10	10
Average	1251.09.00	1006.02.00	1312.04.00

3.5 Control

The purpose of the control stage is to standardize, control and maintain the improved process. The control stage is carried out by compiling standard operating procedures / SOPs with a machine speed of 60 RPM.

4. CONCLUSION

1. Based on research conducted on the post-print process at PT. X, The independent variable in the form of engine speed (RPM) used at the time of the experiment consisted of 3 levels, namely 50 RPM, 60 RPM and 70 RPM with a stack of 5 copies of books.
2. The treatment stage selected based on the Newmann Keuls Student Test is a level 2 experiment with a free variable of 60 RPM.
3. The sigma value obtained in post-improvisation conditions is 2.58 σ, there is an increase in sigma of 0.408 compared to the initial state.
4. The percentage of post-improvement production defects is 4.62%.

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