

CHAPTER 5

RESULTS AND ANALYSIS



This chapter included of conceptual design results, detail design results, the installation of the new web cutter system, implementation results, comparison of before and after implement and assessment of the project success.

5.1 Conceptual Design Results

Conceptual design was conducted prior to and acted as a guide to detailed design of the machine. QFD (Quality Function Deployment) technique was used to translate users' (direct users and indirect users) requirements and expectations into a set of features and characteristics the machine must possess in order to fulfill these requirements. These set of system's requirements was further refined into features needed in each subsystem. The purpose of this conceptual design before the beginning of detailed design was to ensure that the final machine would meet the users' requirements.

From brainstorming of the design team, the draft drawing of the web cutter system was obtained as shown in Figure 5.1.

Web Cutter System

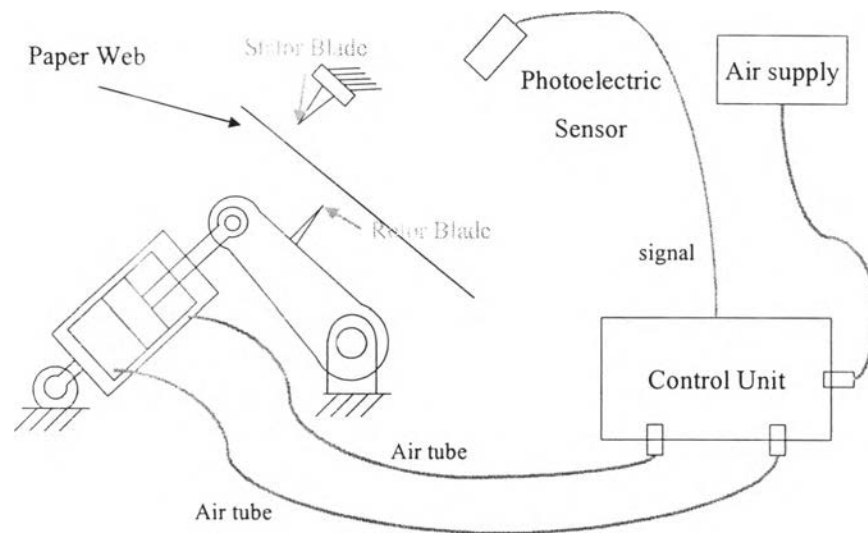


Figure 5.1 Web Cutter System Draft Drawing

When paper breaks, photoelectric sensor transmits the signal to the control unit in order to provide air pressure to pneumatic cylinder. The rotor blade that links with air cylinder will move in order to cut the paper before the paper gets wrapped at the backing roll.

The QFD technique was used to translate the machine modification requirements into design requirements of the web cutting system. As shown in Figure 5.2, the left portion of the matrix shows the list of requirements from the Design Team. Each requirement is matched with the vertical column, which represents the factors that need to be considered in order to satisfy the particular requirement. The result showed that point of installation is most the important factor in the web cutting system design and thus deserves greatest level of attention. Another point that needs serious consideration is the safety system, which is ranked no.2 in term of important in the QFD matrix.

		Whats	How's	Design Requirements					Total	Total%
				Design of Pneumatic system	Design of electrical system	Design of mechanical system	Installation point of web cutter system	Safety system		
Machine Modification Requirements	Web cutter system	To cut paper web in time when paper break	3	○	○	○	○		108	59
		Safe for Operator	4				○	○	48	26
		Do not disturb for cleaning applicator roll and backing roll	2				○		18	10
		Do not disturb for changing backing roll	1				○		9	5
		Importance		27	27	27	66	36	183	
		Importance%		15	15	15	36	20		

Figure 5.2 QFD Matrix for web cutter system

From Draft drawing design, QFD Matrix and brainstorming of the team, design requirements were translated into part design requirement as shown in Table 5.1.

Table 5.1 Out put of web cutter system conceptual design

Design Requirements	Part Design Requirements
<p>1.Design of Mechanical system</p> <p>1.1 The paper has to be completely cut immediately when sheet breaks.</p> <p>1.2 The system must be safe to operate</p>	<p>1.1 Design the cutting blade to cover the paper width. The cutter should have double blades, one fixed in position (stator) and the other moving to cut the paper (rotor).</p> <p>1.2 Safety guard must be installed at the cutting blade to prevent danger to the operator.</p>
<p>2.Design of Pneumatic system</p> <p>2.1 The system must respnd to the occurrences of sheet breaks fast enough.</p> <p>2.2 The system must be safe to operate</p>	<p>2.1 Quick exhaust valve is needed at out let of pneumatic cylinder.</p> <p>2.2 Inlet manual valve is required so that the pneumatic system could be halted when the operator works in the area close to the cutting blade.</p>
<p>3.Design of Electrical system</p> <p>3.1 the system must be able to detect sheet breaks</p> <p>3.2 The system must be safe to operate</p>	<p>3.1 Photoelectric switches should be installed in positions where sheet breaks occur frequently.</p> <p>3.2 Whenever sheet break occurs, the cutter should cut only one time, automatically switched off, and functions again only when switched on.</p>

Table 5.1 Output of web cutter system conceptual design (continues)

4. Installation point of web cutter system	
4.1 the system must be fast enough to cut the paper before wrapped at the backing roll	4.1 the cutting blade should be installed as close as possible to the backing roll, and the distance from the cutting blade to the backing roll should be shorter than backing roll's circumference so that the paper will not get wrapped at the backing roll.
4.2 must be convenient for backing roll cleaning	4.2-4.3 The cutting blade should be installed on machine frame above the working area.
4.3 must be convenient for backing roll changing operation.	

5.2 Detailed Design Results

In this stage, the machine was designed in greater details based on the set of part design requirements identified in the conceptual design phase. This included mechanical parts design, pneumatic system design, and electrical system design. The detail was shown as below.

5.2.1 Mechanical Parts Design

The web cutter system consists of three sets.

1. Rotor Unit – provide support to fix cutting blade for turn to cut paper. This rotor unit consists of the following parts:

- Rotor
- Shaft
- Bearing

- Cylinder Support
- Cutting blade

Figure 5.3-5.7 shows drawing of rotor set.

2. Stator Unit – provides support for the paper during cutting operation. This stator unit consists of the following parts.

- Stator
- Stator Support
- Cutting Blade

Figure 5.8-5.10 shows drawing of stator set.

3. Guard Unit – provide protection for human safety

- Guard
- Support Guard

Figure 5.11-5.13 shows drawing of stator set.

Figure 5.14 shows the pictures of rotor set, stator set and safety guard.

Specifications for the bearing and calculation involved in the design of rotor unit are as following:

1. Specification of bearing

Brand : NTN

Cast Housing Type : UCP210D1

Shaft Diameter : 50 mm.

Bearing Number : UC210D1

Basic Load ratings : Dynamic 27000 N

: Static 20700 N

From calculation, the bearing is subjected to the load of 2851 N while its strength is determined to be 20700 N. This gives a safety factor ratio of 7.2. Details of the calculation can be found in Appendix A.

2. Rotor Design (see detail of calculation in appendix A)

To verify that the rotor can withstand torsion and bending occurred during its operation, computation was made to compare the material shear and bending strengths against the actual shear and torsion occurred during operation. Common practice is to aim for safety factor of 2 or over. Results of the calculation are as follows:

Torsion ; Safety Factor : 15.54

Bending ; Safety Factor : 20.83

Drawing of Rotor Set (for more detail, see Appendix B)

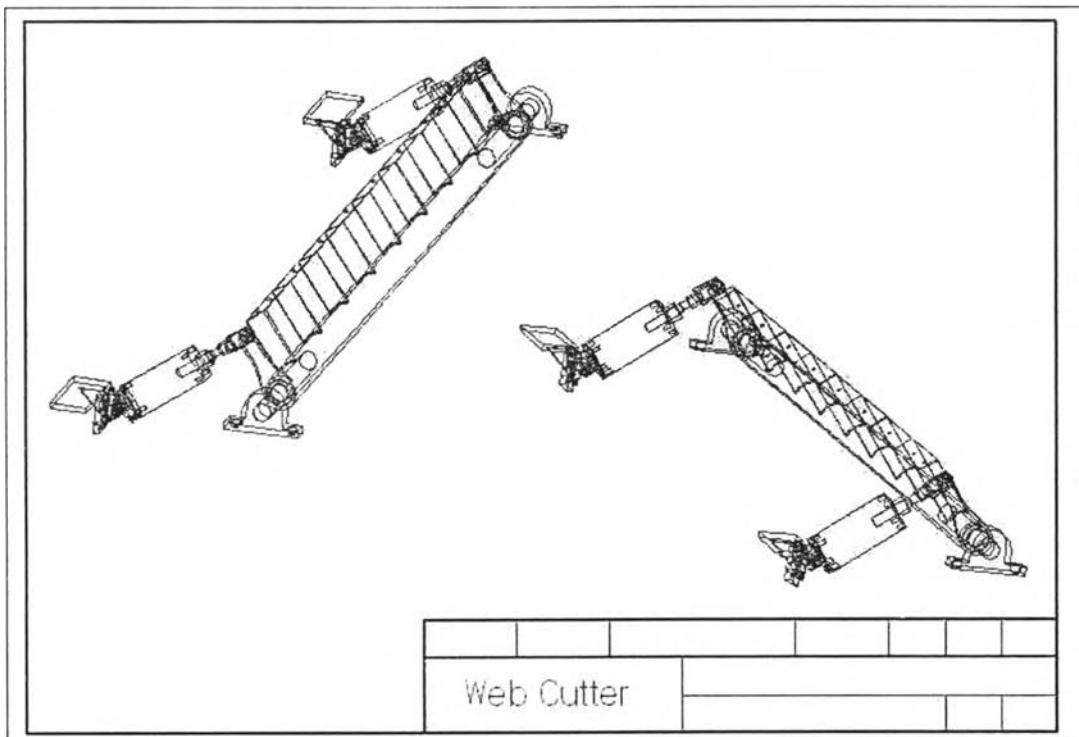


Figure 5.3 : Assembly of Rotor Unit

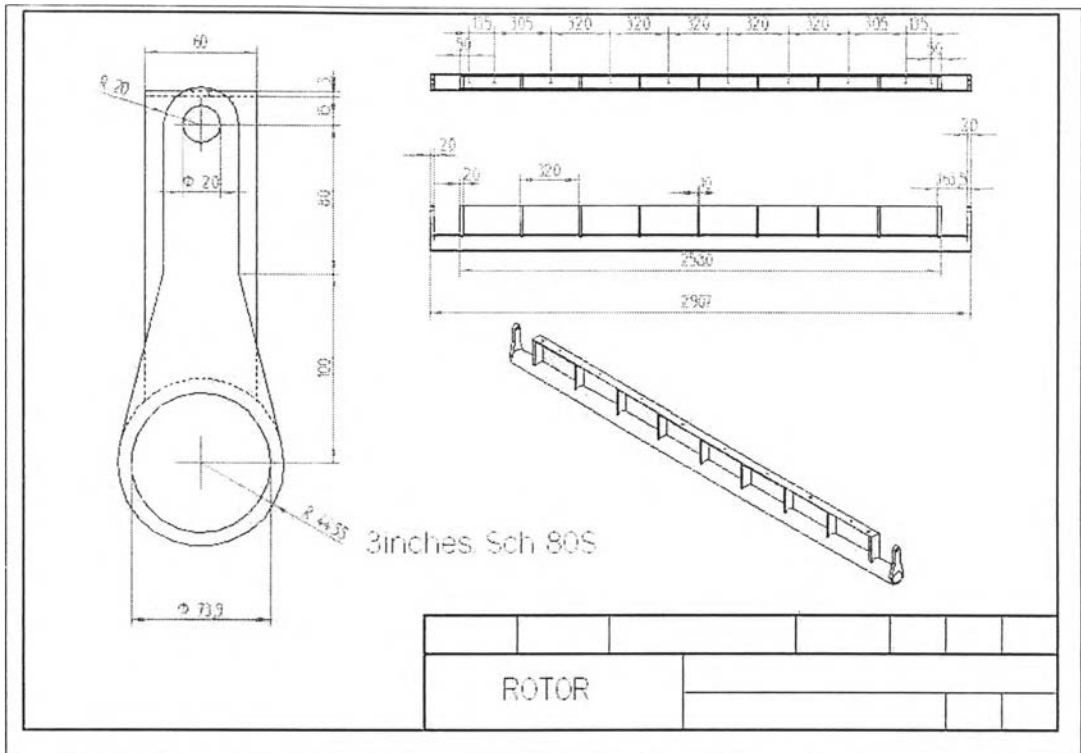


Figure 5.4 : Drawing of Rotor

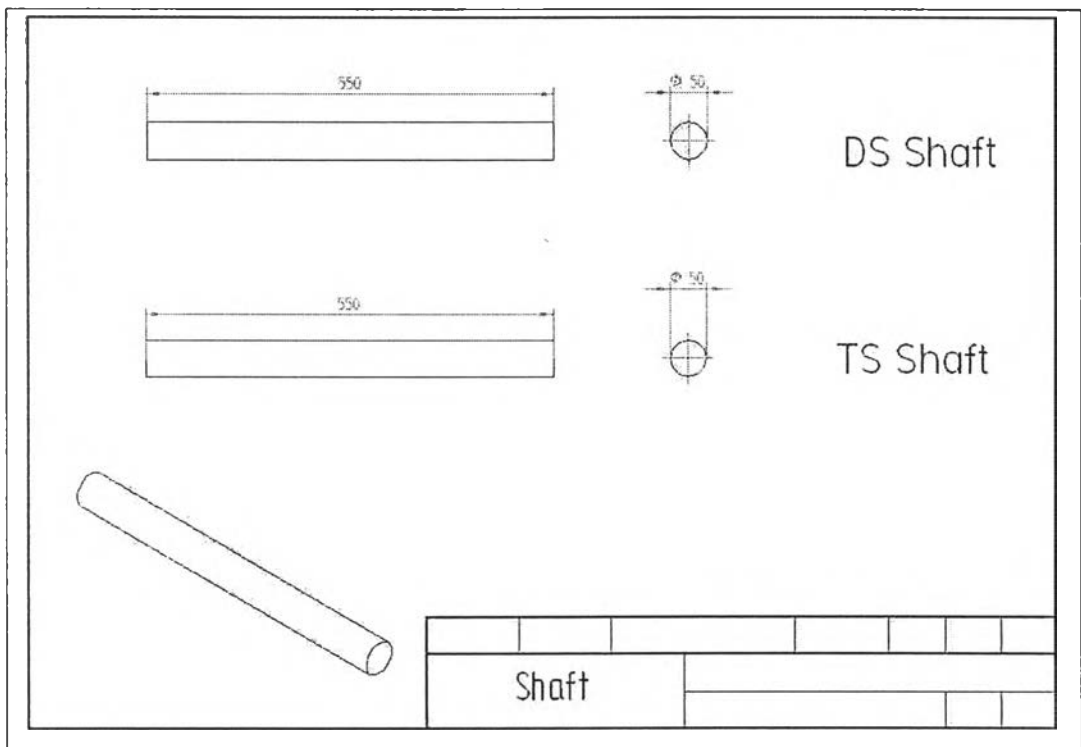


Figure 5.5 : Drawing of Rotor Shaft

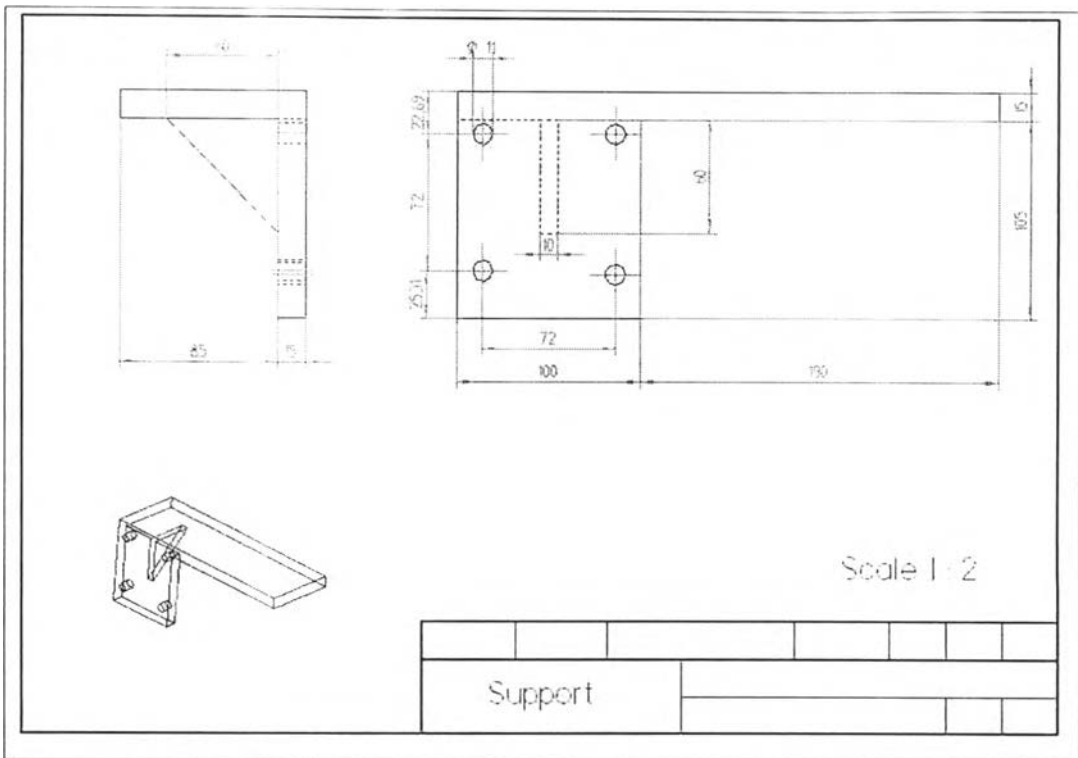


Figure 5.6 : Drawing of Pneumatic Cylinder Support (Drive Side)

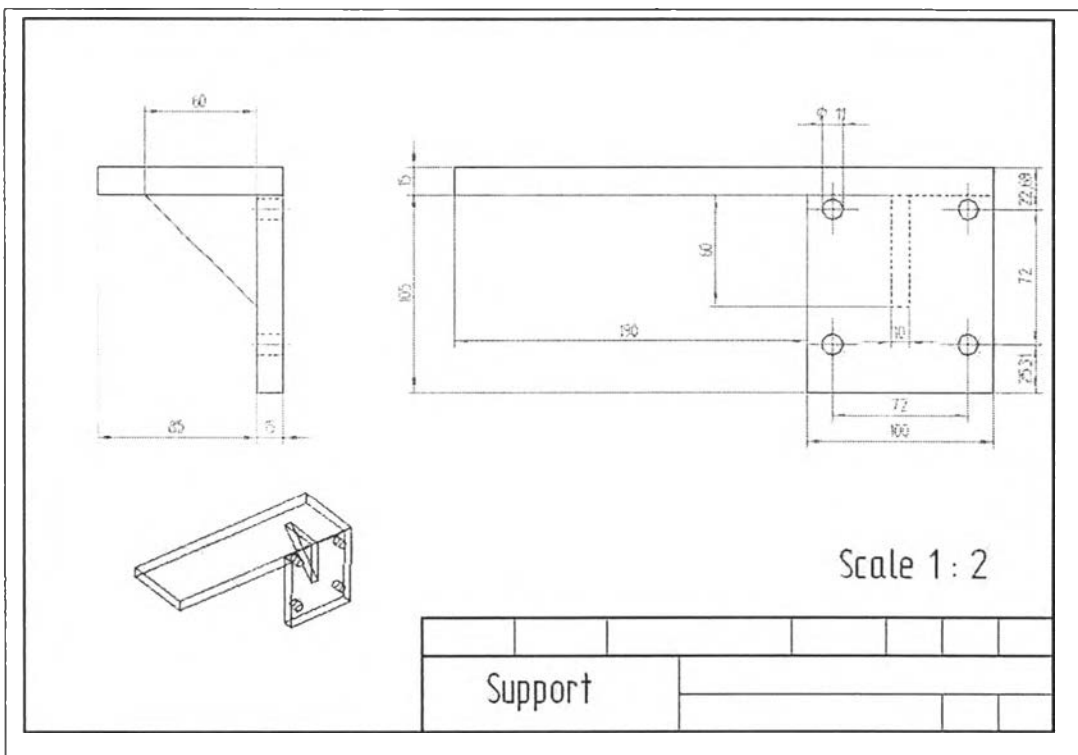


Figure 5.7 : Drawing of Pneumatic Cylinder Support (Tender Side)

Drawing of Stator Unit (for more detail, see Appendix B)

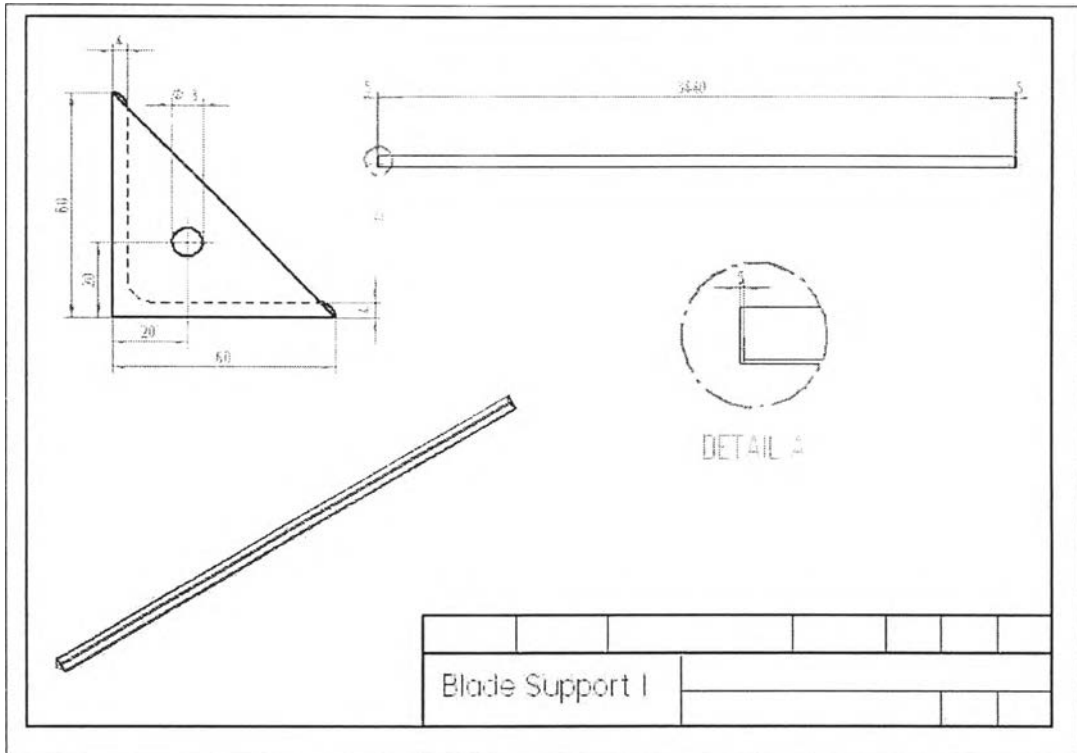


Figure 5.8 : Drawing of Stator

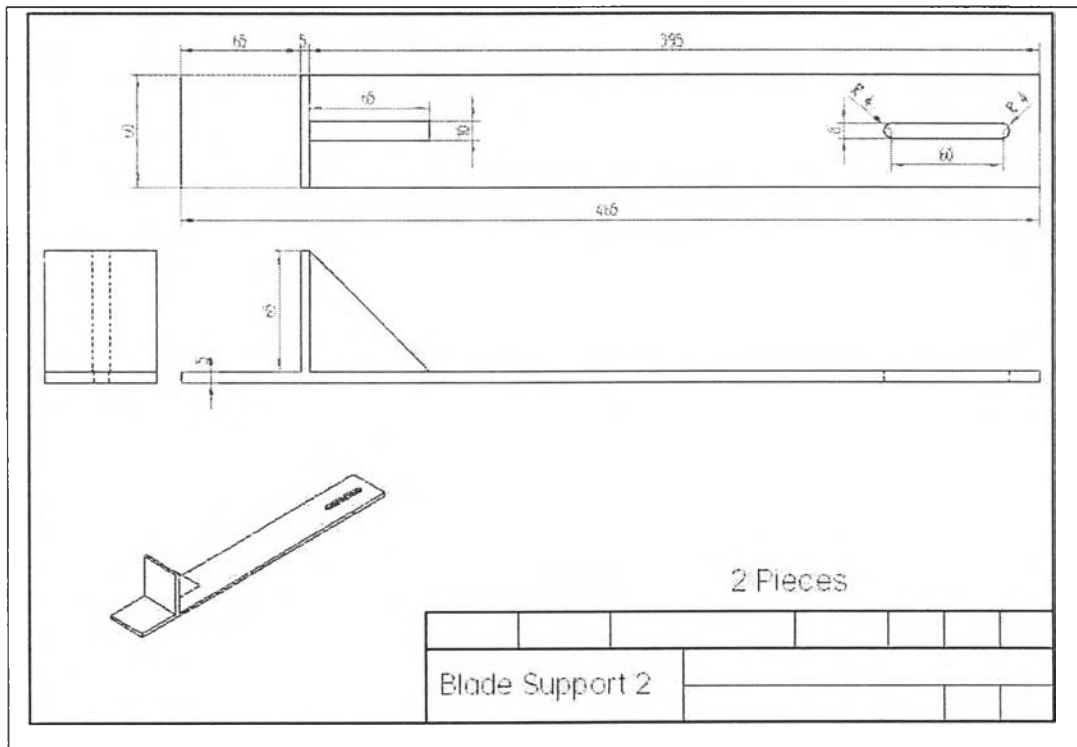


Figure 5.9 : Drawing of Stator Support

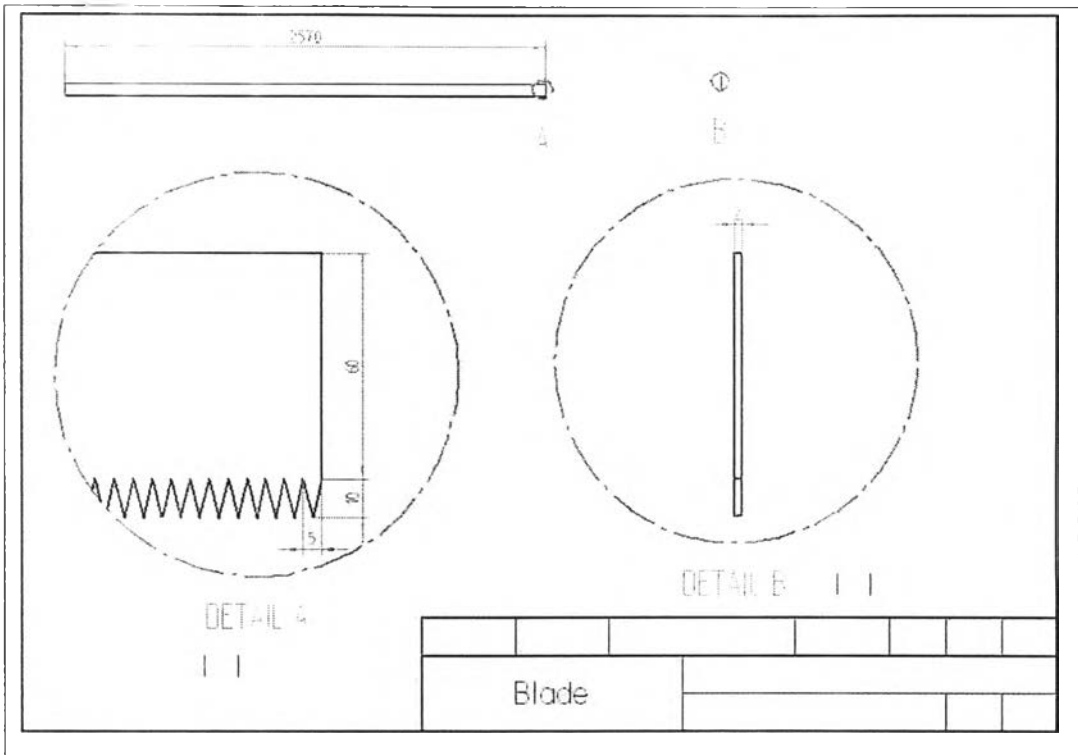


Figure 5.10 : Drawing of Cutting Blade

Drawing of Guard Set (for more detail, see Appendix B)

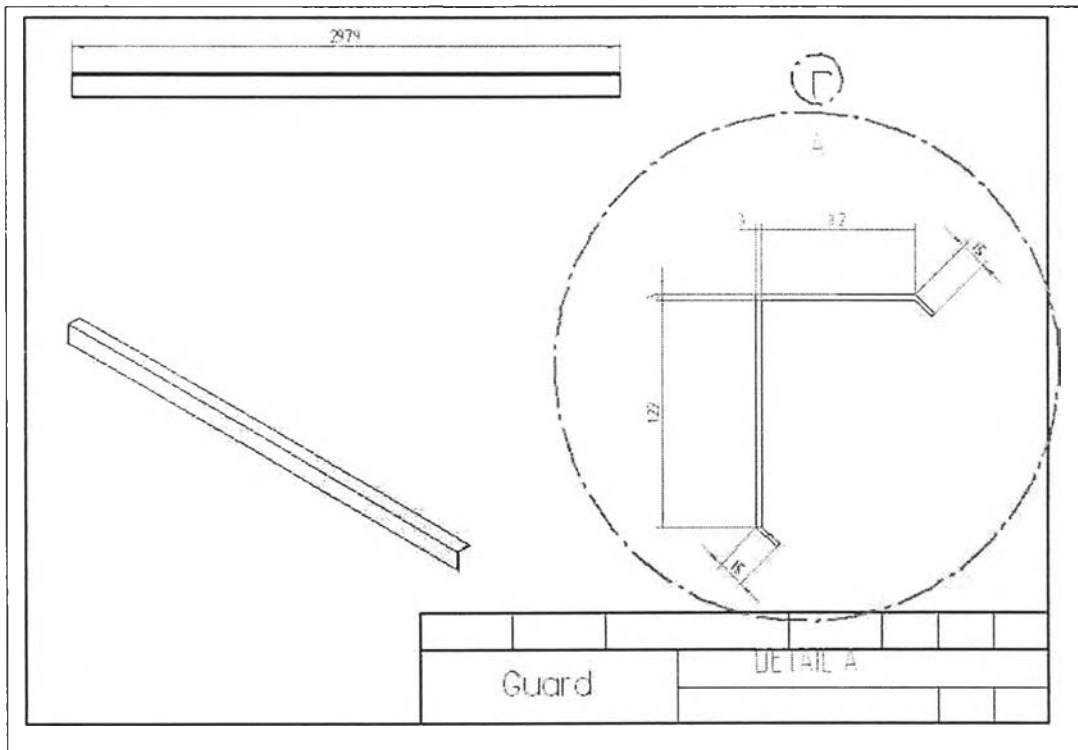


Figure 5.11 : Drawing of Guard

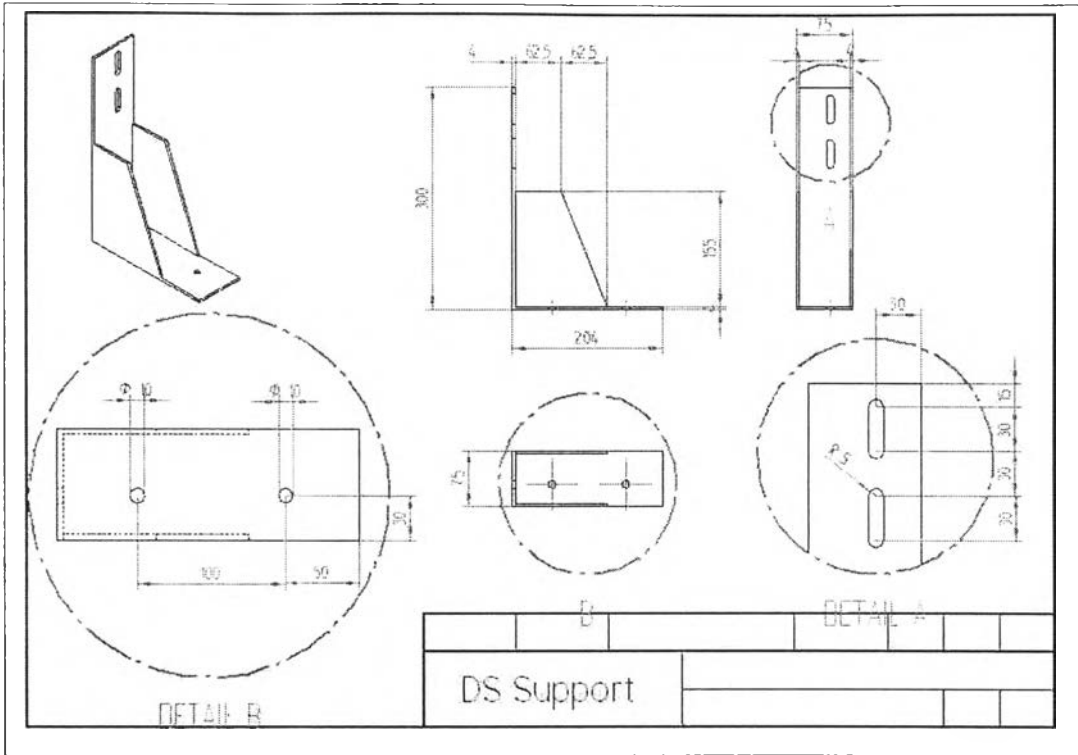


Figure 5.12 : Drawing of Guard Support (Drive Side)

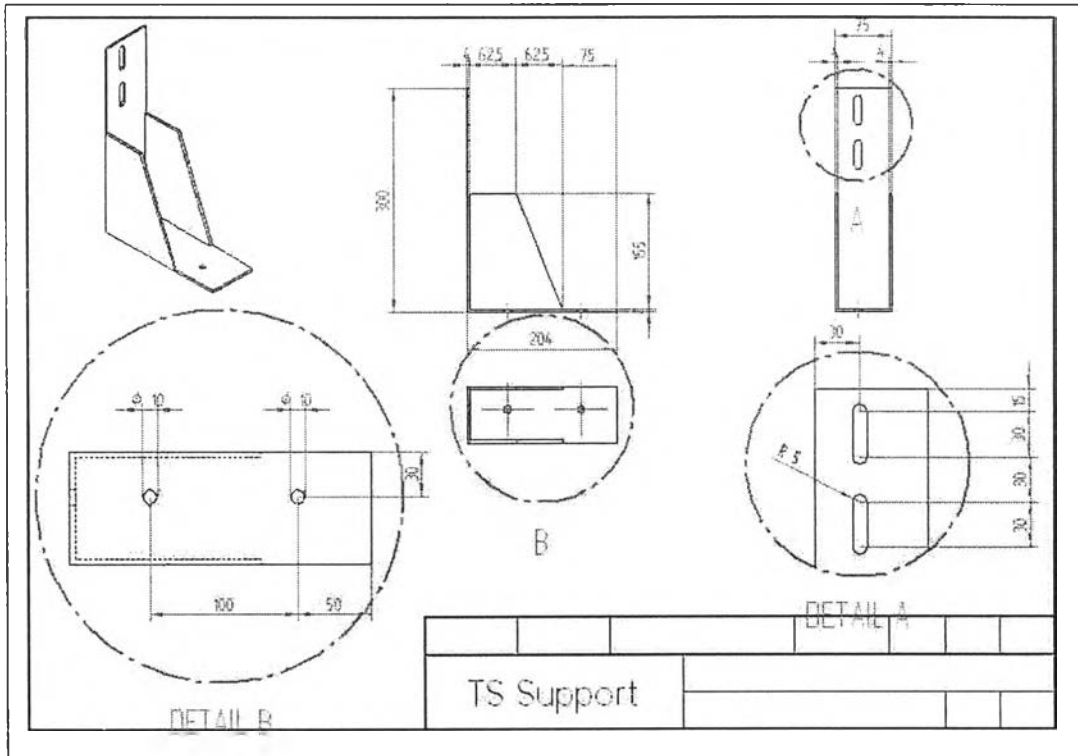


Figure 5.13 : Drawing of Guard Support (Tender Side)

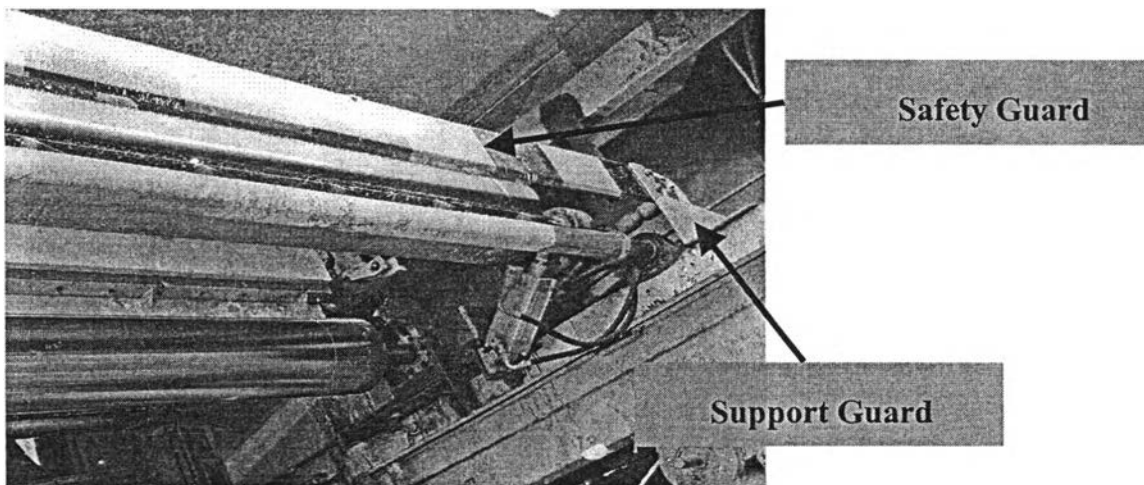
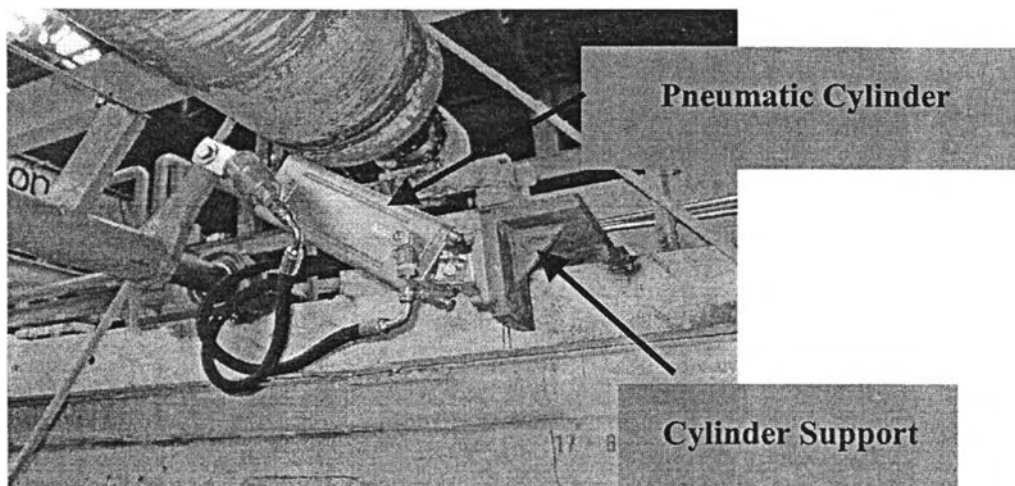
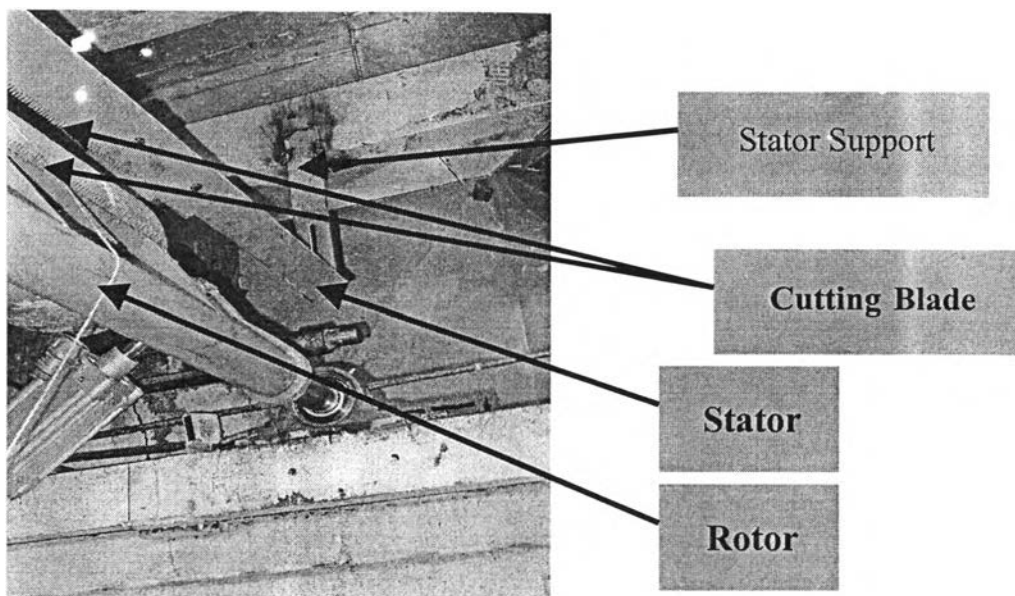


Figure 5.14 : Picture of Rotor Unit, Stator Unit and Guard unit

5.2.2 Pneumatic System Design

Pneumatic Diagram of Web Cutter System

Pneumatic Diagram of Web Cutter System was shown in Figure 5.15 (for more detail, see appendix B)

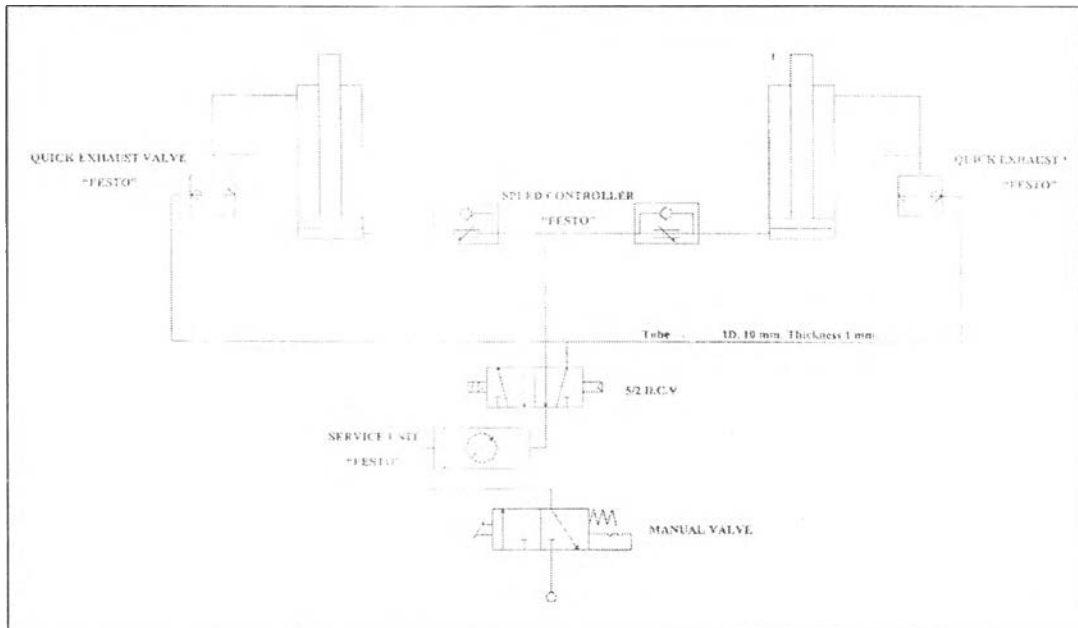


Figure 5.15 : Pneumatic Diagram of Web Cutter System

Specification of Pneumatic System [Festo Catalog, 1997]

1. Double Acting Cylinder

Brand : FESTO

Type : DNC-80-100-PPV

Stroke Length : 100 mm.

Piston diameter : 80 mm.

Return Force : 2720 N

Conection : G 3/8

Max. permissible operating pressure 12 bar

2. Solenoid Actuated Valves

Brand : FESTO
Type : MFH-5/2-D-2-C
Standard Nominal Flow Rate : 2300 l/min
Connection : G 3/8
Operating Pressure : 2 to 10 bar
Solenoid Coil : MFW-230-50/60
Sub-Base : NAS-3/8-ZA-ISO

3. Service Unit Combinations (D-Series)

Brand : FESTO
Type : FRC-1/2-D-MIDI-A
Standard Nominal Flow Rate : 2600 l/min
Upstream Pressure Max. : 16 bar
Operating Pressure Max. : 12 bar
Connection : G ½

4. On-off Valve (D-Series)

Brand : FESTO
Type : HE-1/2-D-MIDI
Standard Nominal Flow Rate : max.3800 l/min
Pressure Range Max. : 16 bar
Connection : G ½

5. One-Way Flow Control Valve - Speed Control Fittings

Brand : FESTO

Type : GRLA-3/8 B

Pressure range : 0.3 to 10 bar

Standard Nominal Flow Rate :

in throttle direction (throttle open) 0 to 1450 l/min

in free flow direction (throttle closed) 780 l/min

Connection/tubing I.D. : G 3/8

6. Quick-exhaust Valve

Brand : FESTO

Type : SEU 3/8 (with integral silencer)

Pressure range : 0.5 to 10 bar

Standard Nominal Flow Rate :

Supply Port to Working Port : 2880 l/min

Working Port to Supply Port : 2280 l/min

Pneumatic Piping Line of Web Cutter System

Pneumatic piping line of Web Cutter System was shown in Figure 5.16

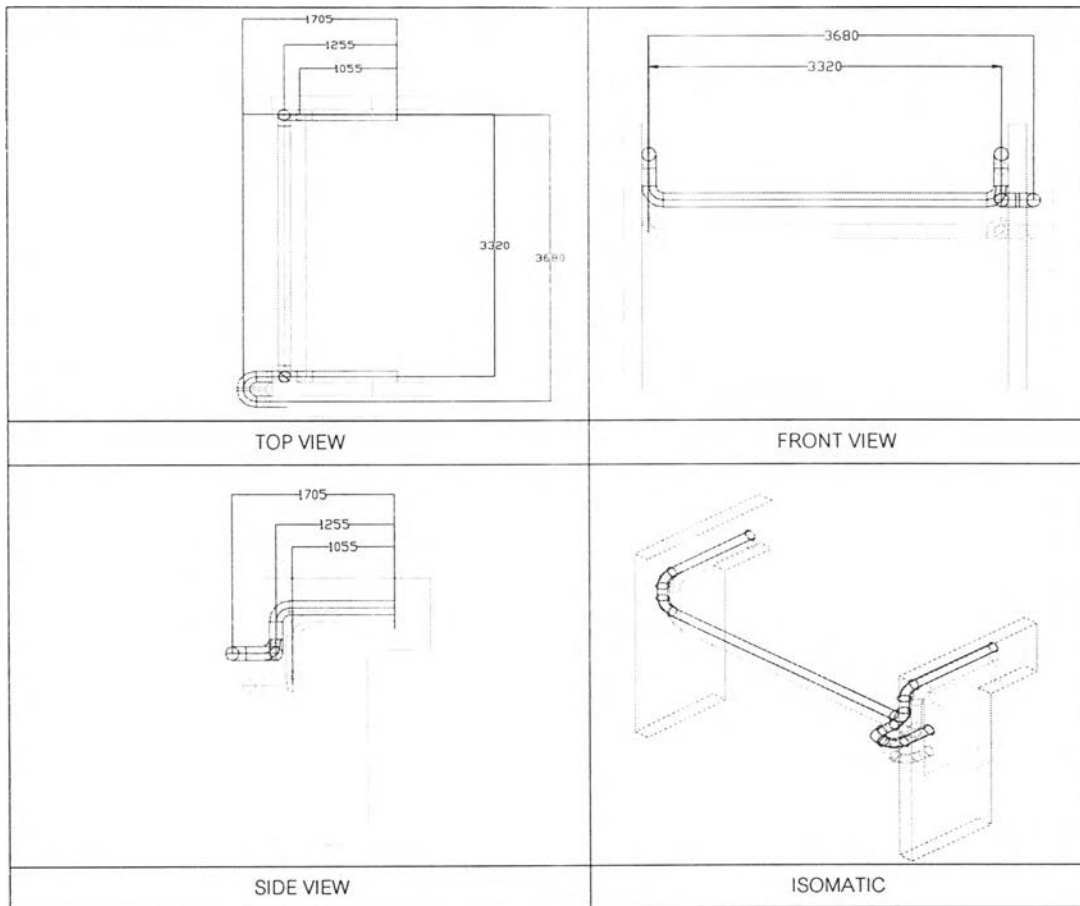


Figure 5.16 : Pneumatic Piping Line of Web Cutter System

5.2.3 Electrical System Design

Electrical design included the design of sheet break detection system. Detection of paper break is done by the use of photo switches. These photoelectric switches are placed along the moving path of the paper and constantly emit infrared wave. When there is paper break, the photo switches will receive no reflection. When paper break is detected, signal will be transmitted to the solenoid valve directing it to start the pneumatic system.

The team planned to install the photoelectric switches in the areas where paper break occurred frequently. These were the 6 positions shown in Figure 5.17.

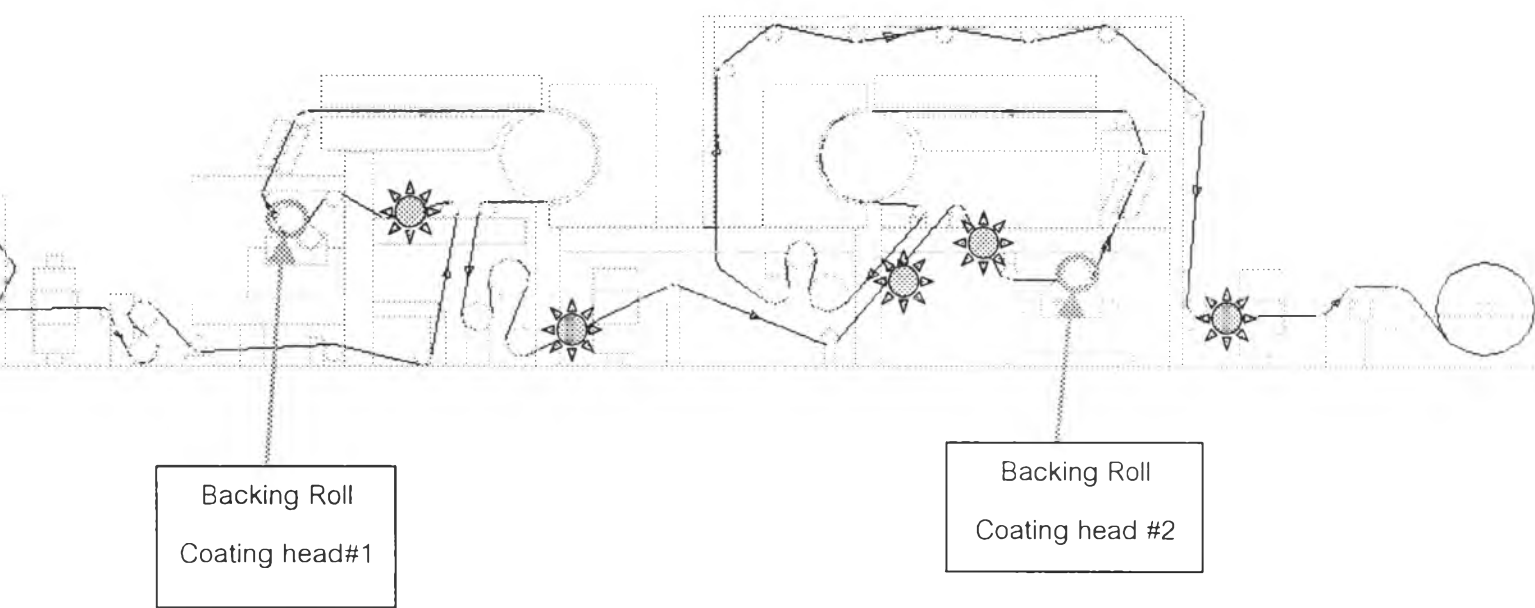


Figure 5.17 : Positions of Photoelectric Switches

Specification of Photoelectric Switch

Brand : CARLO GAVAZZI (more detail, see appendix C)

Type : Diffuse reflective

Sensing range : 0 to 1,000 mm.

Supply voltage : 10-30 VDC

Figure 5.18 and 5.19 illustrate how the electrical paper break detection system works.

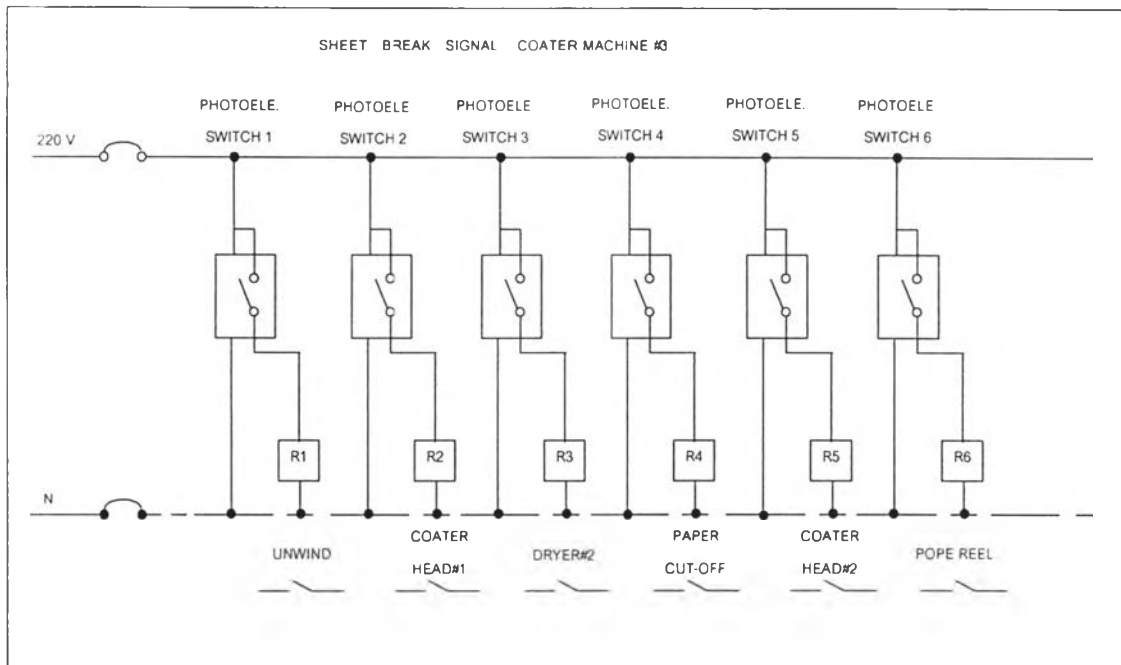


Figure 5.18 : Photo Electric Switch Circuit

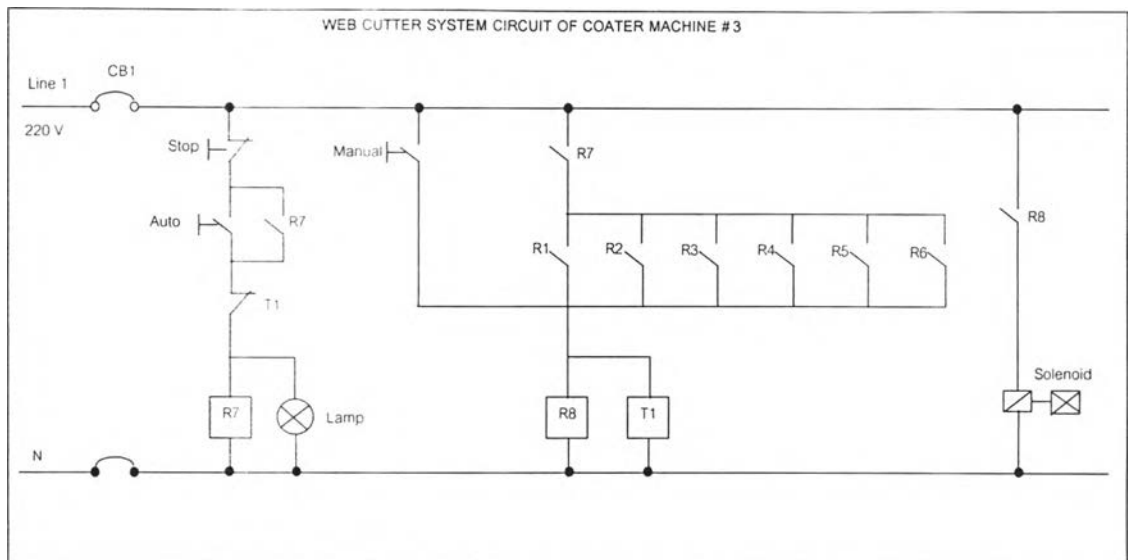


Figure 5.19 : Web Cutter System Circuit

5.3 Installation and Implementation Results

5.3.1 Installation point of web cutter system

This section discussed about the installation process, limitation and problems encountered during the installation. To prevent backing roll damage from paper jammed, the team had brainstorm and concluded that the web cutter system should be installed on coating head no.1 and coating head no.2 as follow.

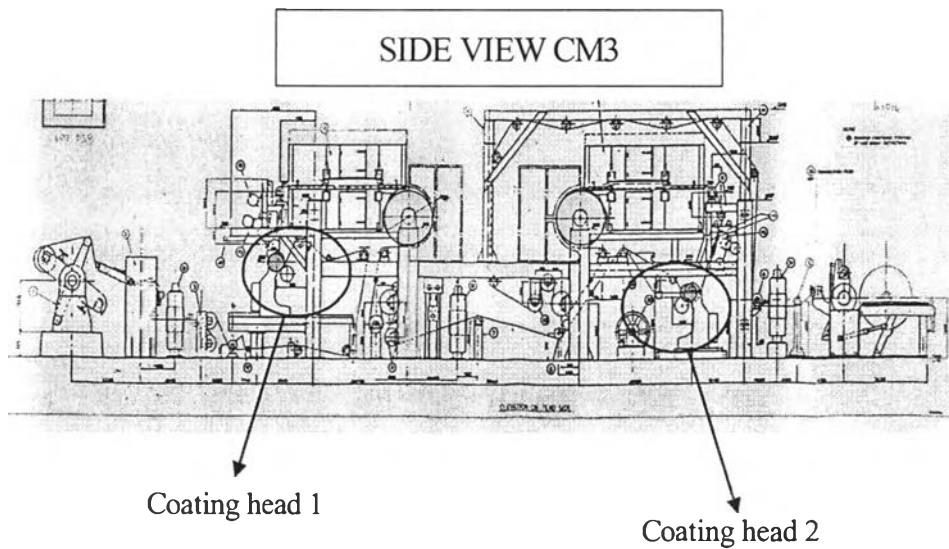
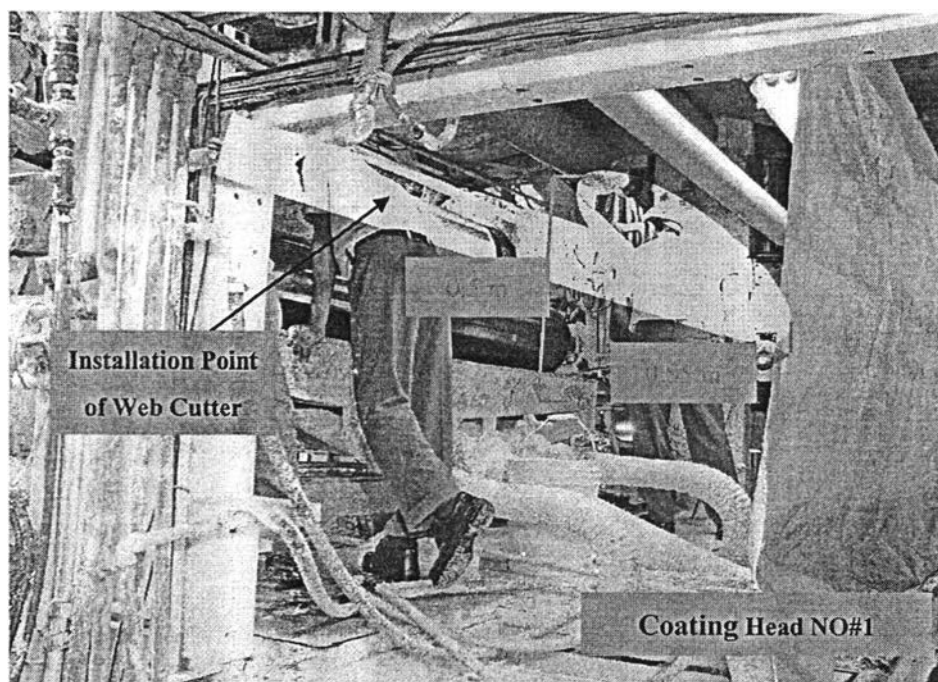
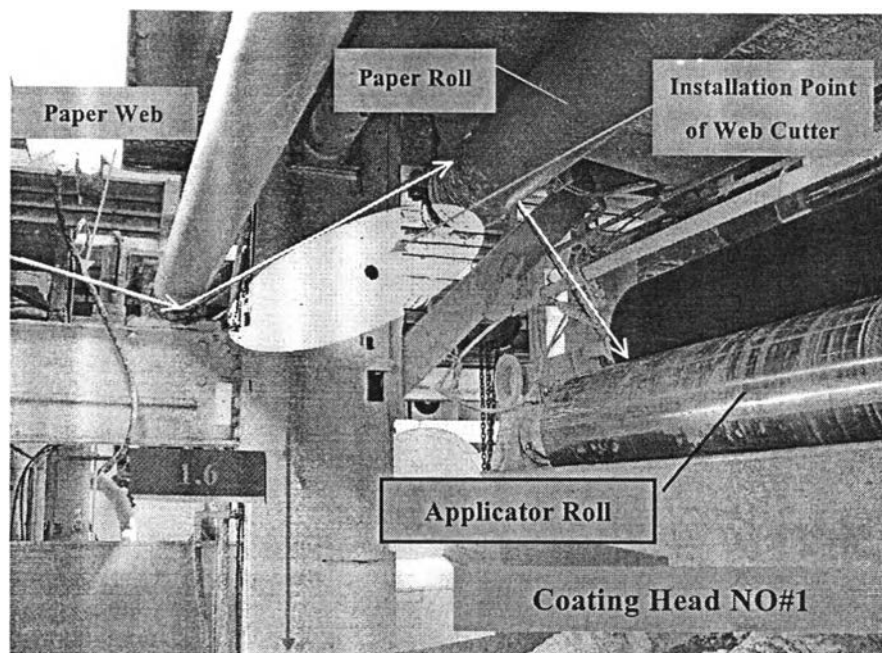


Figure 5.20: Layout of the existing coater machine.

After survey coating head no#1 and coating head no#2, there are limited space on coating head no#1. The operator has no space to cleaning backing roll and applicator roll as shown in Figure 5.21-5.22. Therefore, the web cutter system had been planned to install on coater machine at coating head no#2.



For installation at coating head no#2, the most suitable point of installation should be set close to backing roll as shown in Figure 5.23. However, in reality this is not practical because of limited available space. Therefore, web cutter system was installed on machine frame before coating head no#2 as shown in Figure 5.24 and 5.25. The reasons for installing web cutter in this position were listed as follows.

1. The operator has enough space for cleaning backing roll and applicator roll.
2. It is convenient for changing backing roll.
3. It is safe for operators because cutting position is adequately above the working area.

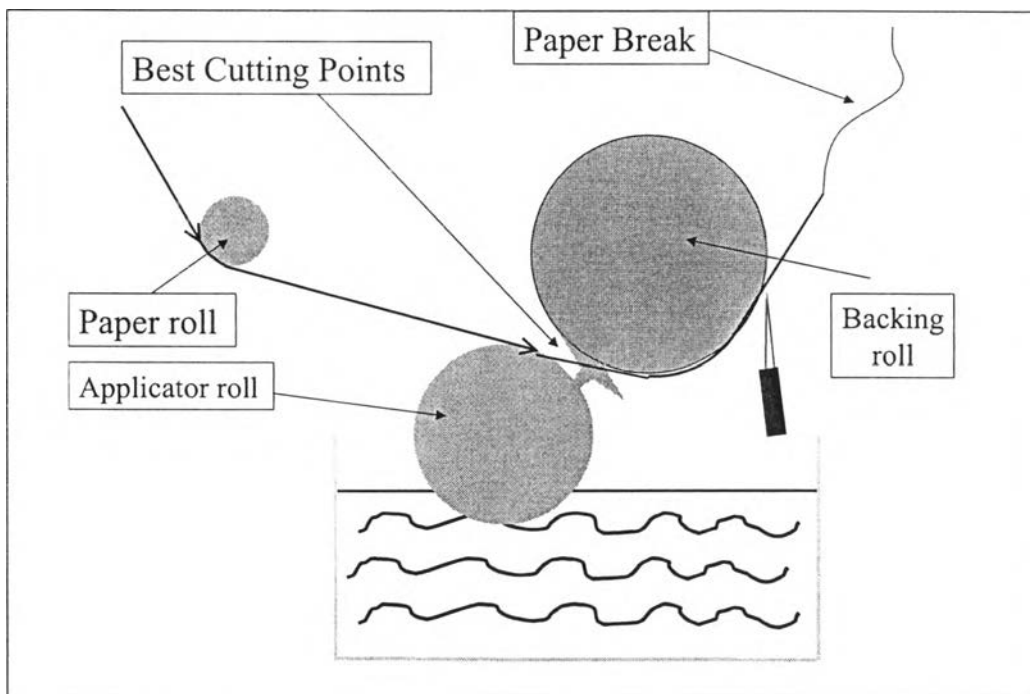


Figure 5.23: The best cutting points of web cutting system

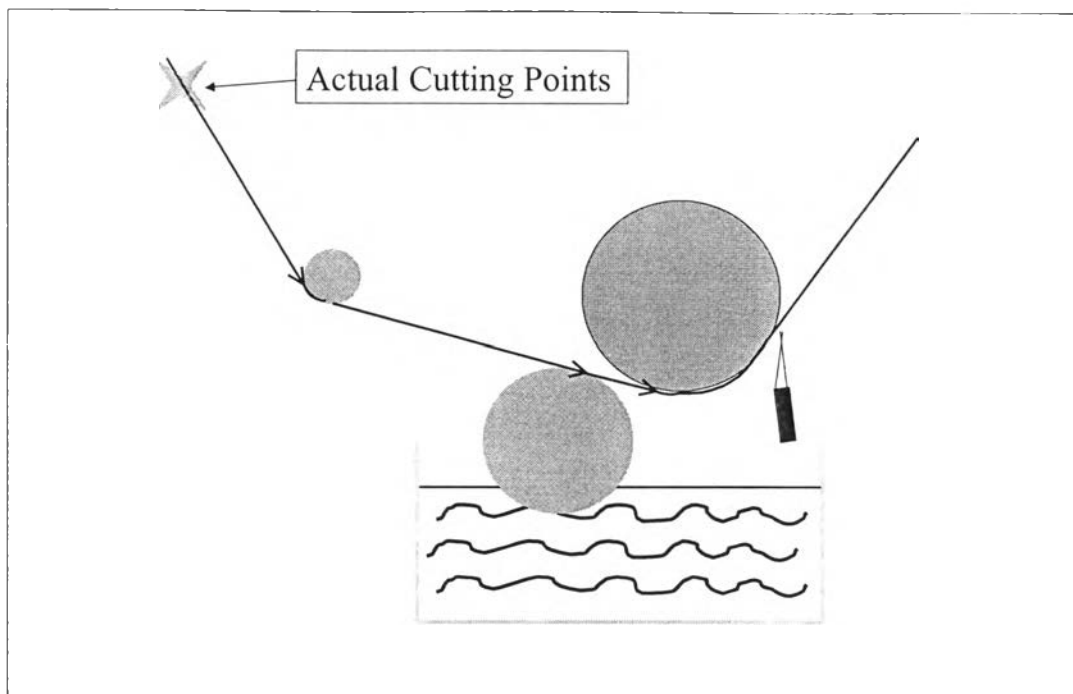


Figure 5.24 : Actual Cutting Point of web Cutter System

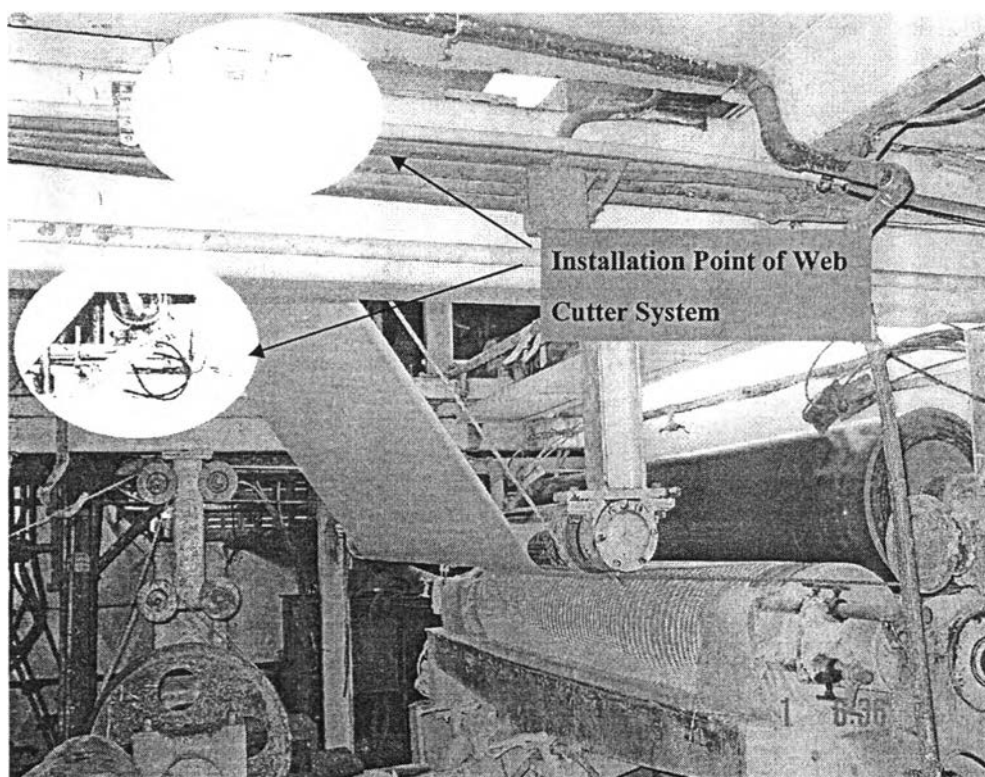


Figure 5.25 : Coating head No#2 at Right Side View

To prevent the paper wrapped at the backing roll, the length of paper cut must be shorter than the circumference of the backing roll. The calculation data for web cutter system at coating head no#2 was shown in Appendix D.

5.3.2 Installation of web cutter system

The installation was done during scheduled shutdown period on 30 October 2002.

Following are parts that had been installed shown along with the photos.

1. The mechanical parts (rotor set, stator set, safety guard) were installed on machine frame at coating head no#2 as shown in Figure 5.26.
2. Pneumatic system: Figure 5.27 shows the control unit of the system.
3. Electrical system: Figure 5.28 shows control panel of the system and photoelectric switch. Photoelectric switches were installed in the positions as designed.

Figure 5.29 shows web cutter system in operation.

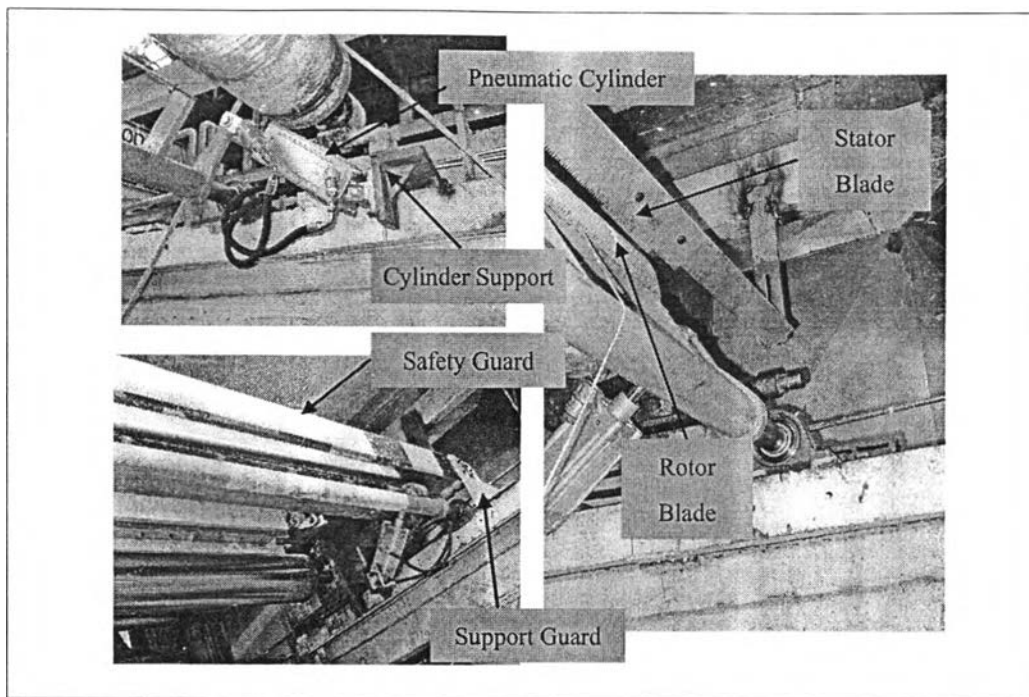


Figure 5.26 : Installation Parts of Web Cutter System

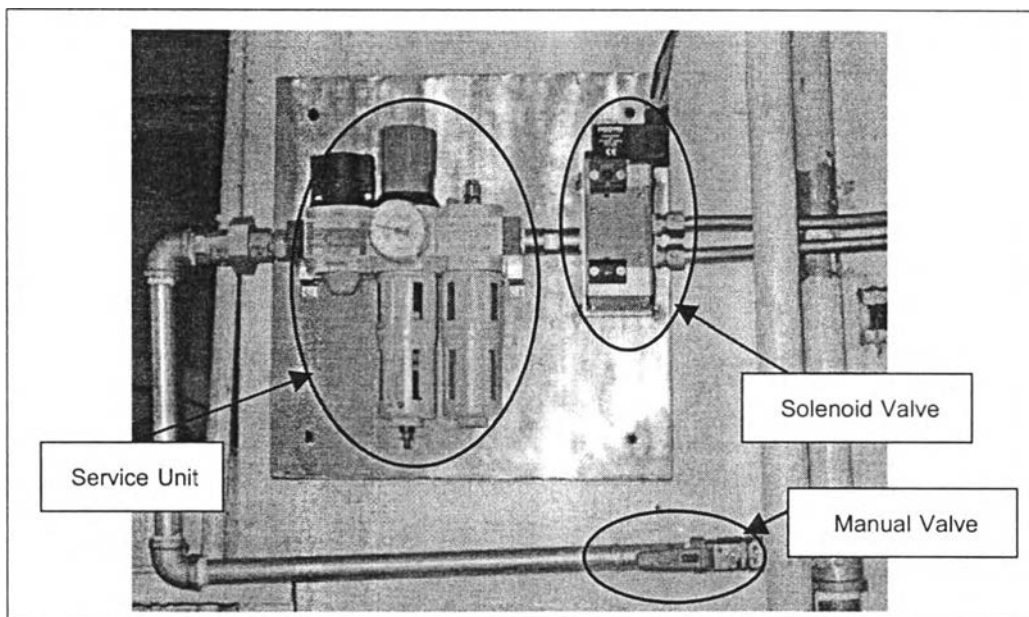


Figure 5.27 : Control Unit of Web Cutter System

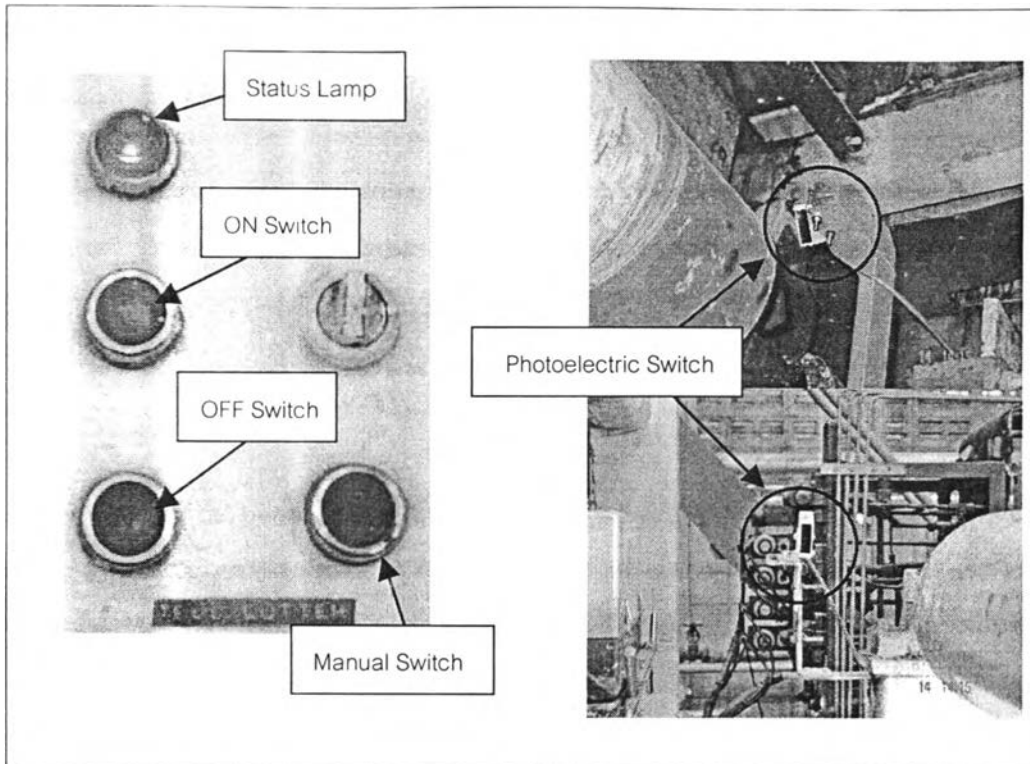


Figure 5.28 : Control Panel and Photoelectric Switch

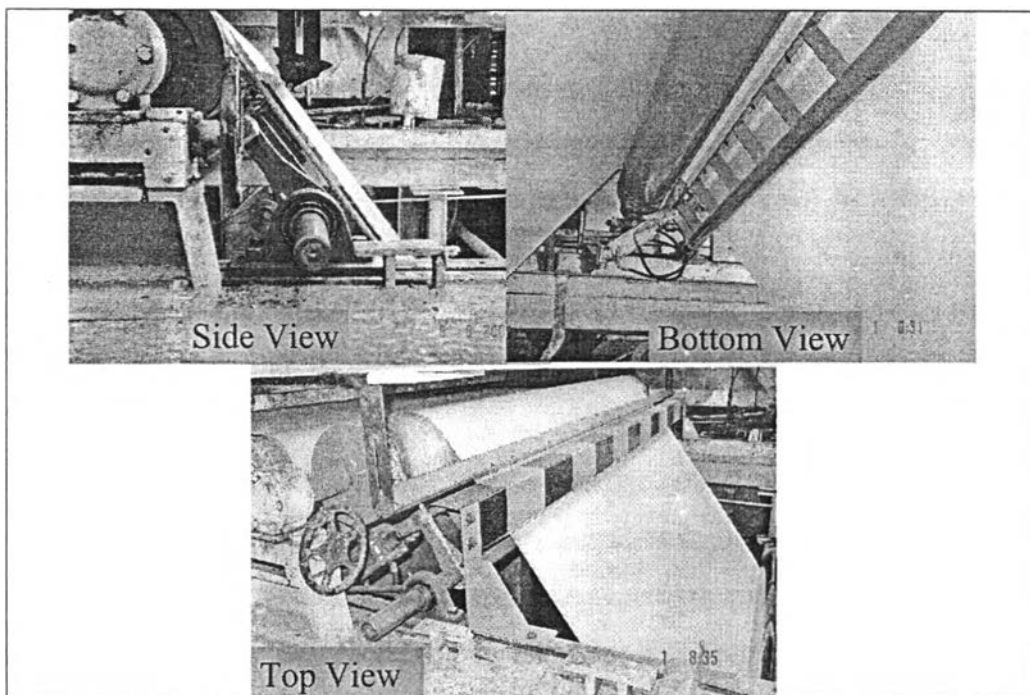


Figure 5.29 : Web Cutter System in Operation

5.4 Comparison of before and after implement

After the cutting system had been installed, an observation was made during November 2002 to February 2003 to determine the effects of the newly installed cutting system. Two areas were observed which were machine runnability and amount of sheet break loss time.

5.4.1 Machine Runnability

Figure 5.33 shows machine runnability expressed in term of percentage of times the cutting system successfully cut the paper before it gets wrapped at backing roll. From the figure the machine runnability appeared to be quite low in the first two months after implementation. The runnability percentage was just 46.67 and 53.33 in November and December respectively.

Improvement by adjust sensitivity of photoelectric switches

Seeing this relatively very low machine runnability, the Design Team investigated into the problem and found out that it was the inappropriate setting of some photoelectric switches' sensing ranges that had caused the problem.

The effects of inappropriate sensing ranges are explained as follows; (see sensitivity adjustment in appendix C)

1. Too long sensing range - making the system unable to detect paper break in some occasions. The paper normally sags when sheet break occurs, increasing the distance between the photoswitches and the paper. If the sensing range was set properly, the saged paper will be out of the sensing range, indicating the occurrence of sheet break. However, if the sensing range was set to long, the paper will remain detected as normal, causing the cutter to start function late (see Figure 5.30).

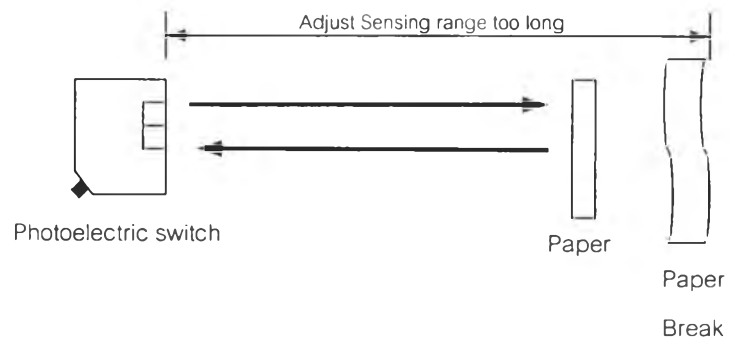


Figure 5.30 : Adjusting sensing range too long

2. Too short sensing range – making the system interpret the result as paper break, even when there is no real paper break. The result will be cutting of paper despite the fact that no paper break occurs (see Figure 5.31).

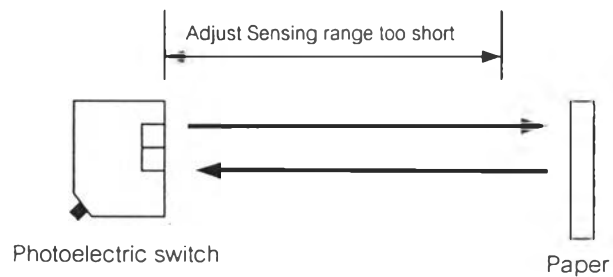


Figure 5.31 : Adjusting sensing range too short

Investigation into the problem suggested that the sensing range of some photoelectric switches were set too long. After the cause was known, the Team corrected the problem as follows.

1. Measured the distance from photoelectric switches to the paper in every position.
2. Adjusted photoelectric switches according to the measured distances. A tolerance of about 2 centimeter was given to allow for the paper movement during machine operation (see Figure 5.32).

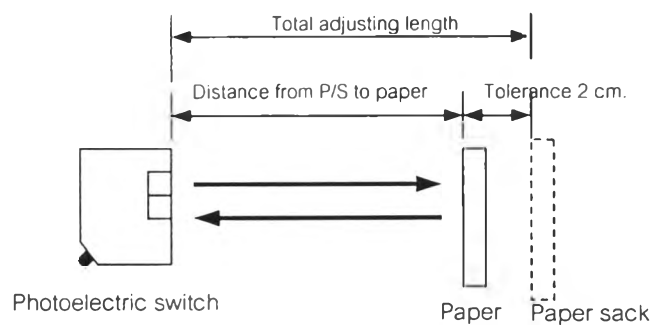


Figure 5.32 : Total adjusting length of photoelectric switch

After this improvement, the runnability appeared to improve substantially. The runnability percentage rose to 94.83 in January 2003 and even increased slightly to 97.83 percent in February 2003 (see Figure 5.33). This is the best achievable condition in practice as it is hard to be 100 % efficient due to the necessary tolerance for paper moving as explained earlier.

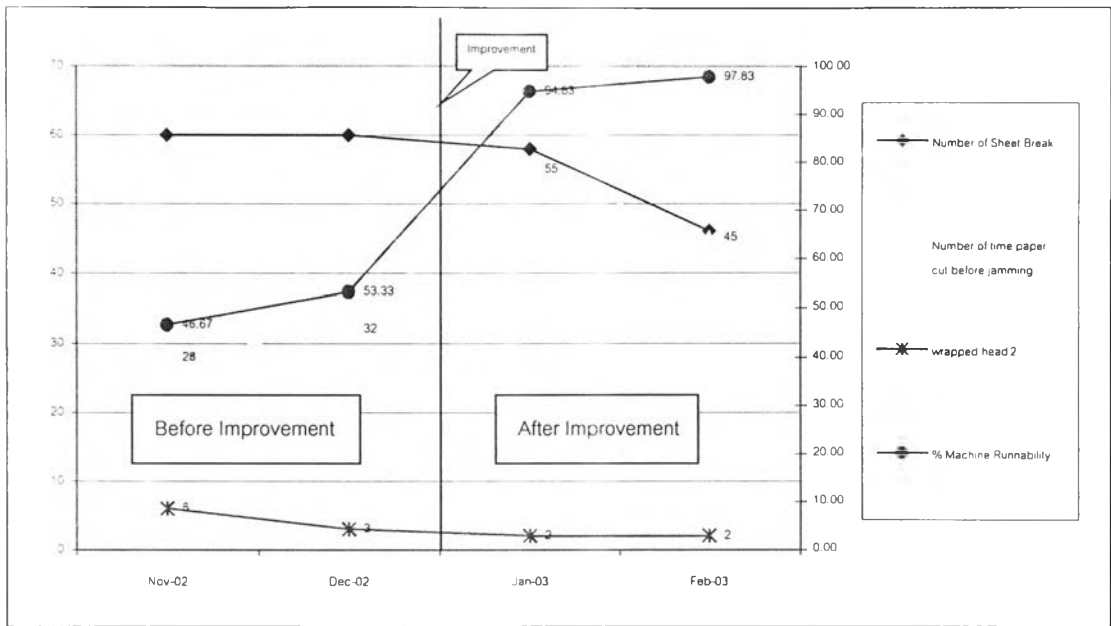


Figure 5.33 : Machine runnability

Data of graph in Figure 5.33 was shown in Table A.4 (see appendix E).

5.4.2 Sheet Break loss time

Figure 5.34 shows a significant reduction in paper wrapped at backing roll after the cutting system was put in place. The result was decrease in the amount of time required to clean up and remove the wrapped paper. Figure 5.35 shows the sheet break loss time prior to and after implementing the new cutting system. A remarkable decrease in sheet break loss time could be observed after the cutting system was installed. Average sheet break loss time at coating head 2 (where the cutting system was installed) dropped to 80 minutes per month compared to 680 minutes before installing the cutting system. This in turn helped reduce to total sheet break loss time (coating head 1 and coater head 2 combined) from 2477 minutes per month to 1767.5 minutes. (see more detail of collected data in appendix E).

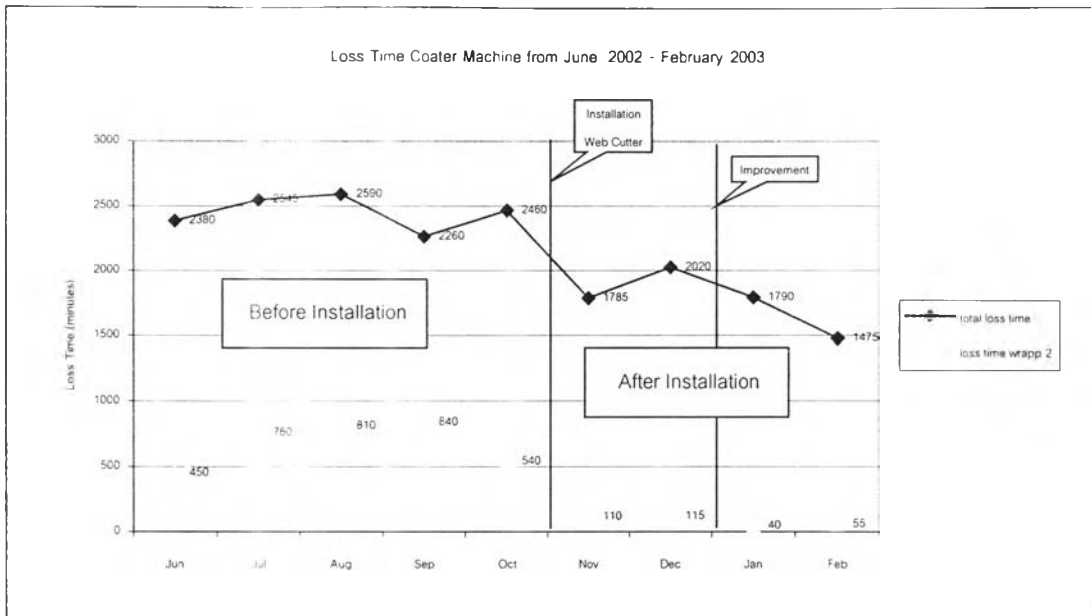


Figure 5.34 : Sheet Break loss time of Coater machine

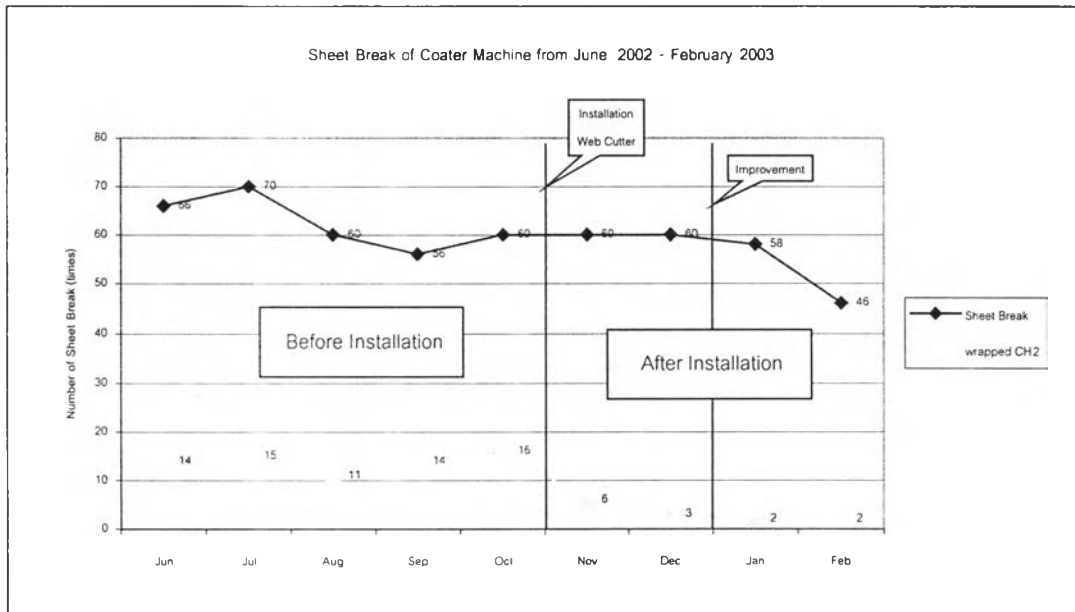


Figure 5.35 : Number of time of Sheet break

Data of graph in Figure 5.34-5.35 was shown in Table A.3 (see appendix E).

5.4.3 Cost saving from implementation web cutter system

Cost of implementing the new cutting system is detailed as follows.

Investment Cost of Web cutter System

1 Rotcr,Stator&Knife	15,000 baht
2 support	6,000 baht
3 piping for pneumatic	5,000 baht
4 safety guard	6,000 baht
5 double acting cylinder	11,392 baht
6 one way flow control valve	1,548 baht
7 wartungseinheit (regulator,filter)	3,190 baht
8 double solenoid valve	7,258 baht
9 quick exhaust valve	1,802 baht
10 System and engineering design	30,000 baht
11 others	5,000 baht
12 work force	6,000 baht
total	<u>98,190 baht</u>

There are 2 benefits that attained from the new web cutter system were as

1. Saving cost from reducing sheet break loss time.
2. Saving cost from backing roll maintenance

Detail of cost saving was shown below.

Saving Cost from Implementing Web Cutter System

1. Saving Cost from reducing sheet break loss time

1.1 Productivity loss

Production	4 ton/hour
Average Contribution for Coated Paper	8,000 baht/ton
Average productivity loss	32,000 baht/hour

1.2 Average sheet break loss time of coating head no#2 reducing	10 hrs/month
Average saving cost from production increasing	320,000 baht/month
	<u>3,840,000 baht/year</u>

2. Saving Cost from Backing Roll Maintenance

2.1 Cost for Grinding Backing roll	by Mill	5,000 baht/time
	Out source	44,900 baht/time
2.2 Backing roll cost (new)		350,000 bath/roll

Total investment cost of Web Cutter System is 98,190 Baht. And saving cost of implementing Web Cutter System was 3,840,000 Baht per year.