

# Construction of Machine Model for Corrugated Board Making in Paper Laboratory

Wittaya Kaewsubsak\*, Suchapa Netpradit, and Tanatorn Tongsumrith

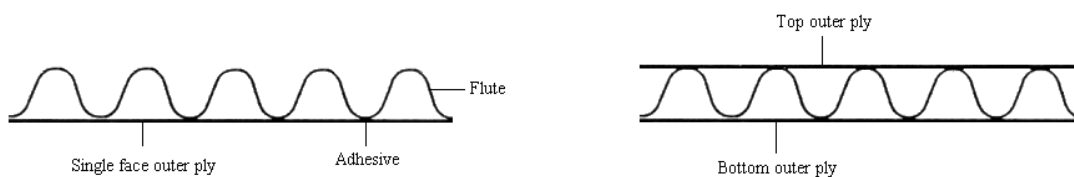
Department of Printing and Packaging Technology, Faculty of Industrial Education and Technology  
King Mongkut's University of Technology Thonburi  
126 Pracha-Utit Rd., Bangmod, Thungkru, Bangkok 10140, Thailand  
Corresponding author's e-mail: wittaya.kae@kmutt.ac.th, turbo\_stage@hotmail.com

**Abstract:** The objectives of this project were to construct a set of corrugator model for use in paper laboratory, to test of machine efficiency in making corrugated board, and to evaluate the satisfaction of technicians from corrugated board manufacturing. A set of machine model is consisted of 3 units; flute forming unit, gluing unit, and liner lamination unit. The flute forming unit provides a pair of gear-like rolls for simulated C-flute forming that can be heated and the steam system at the feeder. To test of the machine efficiency, the single-wall corrugated board sized of 297 x 420 mm was produced by using 125-g craft paper as corrugating medium and 160-g craft paper as liner. The different temperatures of heated rollers in flute forming unit were studied with and without steam jet. In addition, the optimum glue amount supplied on the fluted tips and the roller pressure for flat liner pressed against the flute were also analyzed. Then the C-flute corrugated board was taken for testing of the physical properties. The results showed that the V-shape C-flute tip formed at 180° C with steam system had the mean height of 3.8 mm and the mean width of 7.5 mm which were within Thai Industrial Standard (TIS.) No. 550-2528. For the produced corrugated board, the burst resistant was 1093.87 KPa, the flat crush resistant was 631.67 N, and the edge crush resistant was 390.50 N, which all properties were acceptable compared to the industrial corrugated board and the values are within the standard critical. The evaluation by the experts showed that the structure design, application, characteristic and production of the machine was good.

**Key words:** Corrugator, Corrugated board, C-flute, Craft paper, Paper laboratory

## 1. INTRODUCTION

Corrugated Board is a high performance packaging material designed to pack, protect and promote products. It is a natural, environmentally friendly material with an unbeatable record for recycling and recovery. The corrugated board panels used in the containers are sandwich structures consisting of two flat plates called liners, which are separated by a sine wave shaped fluted core referred to as the corrugating medium, as shown in Figure 1. In manufacturing, the rolls of liner and medium paper are combined into corrugated board in a corrugator. Corrugated Board offers tear, tensile and burst strength to withstand shipping pressures. It resists impact, drop and vibration damage, and offers uniform stacking and weight distribution.



**Fig. 1** Single face corrugated board (left) and double face corrugated board (right)  
[http://www.tis-gdv.de/tis\\_e/verpack/papier/wp\\_arten/wp\\_arten.htm](http://www.tis-gdv.de/tis_e/verpack/papier/wp_arten/wp_arten.htm)

To improve the corrugated board qualities, the manufacturer should have a laboratory for research and development. The factors affected the corrugated board properties must be studied and the simulated model of corrugated board should be produced to test of the properties before running the real production line. The general corrugator machines are very large with the width of 48 inches, consist of mill roll stand, single facer, conveying bridge, glue machine, double facer, slitter scorer, cut-off stacker and so on, which is very trouble and cause high cost for test the production.

Presently, the instrument for forming a corrugating medium used in many paper laboratory is the Concora medium fluter, which can produce the small size of medium (1 x 10 cm) and be too expensive. Therefore, the corrugator machine model that is able to produce the large size of corrugated board and provide low cost for test the production should be constructed simulate to the corrugator machine in the factory, in order to use in the paper laboratory.

## 2. METHODOLOGY

### 2.1 Construction of the Machine Model for Corrugated Board Making

The machine layout was designed, the equipments were prepared, and the machine model was constructed. A set of machine model is consisted of 3 units as follows:

#### 1) Flute forming unit

The flute forming unit provides a pair of gear-like steel rolls for simulated C-flute forming that were produced by milling process. They can be heated by the conductive coil inside the rolls, rotated by driving motor, and set the pressure between two rolls by screw adjustment. At the paper feeding area, the steam system was set across the table using a metal pipe with many tiny holes, connected from the water boiler. This unit can work by a set of electrical supplied controller.

#### 2) Gluing unit

The gluing unit is included of a pair of rolls that get the glue from a reservoir and then supply on the fluted tips of the corrugating medium. The pressure of 2 rolls can be adjusted by screw and the distance between blade and roll can be adjusted by a driving motor.

#### 3) Liner laminator unit

The liner lamination unit is included of a pair of pressure roll rotated by driving motor, and set the pressure between two rolls by screw adjustment.

### 2.2 Production Test of Single-wall Corrugated Board

The single-wall corrugated board sized of 297 x 420 mm was produced by using 125-g craft paper as inner medium and 160-g craft paper as liner. To select the best related factor, the corrugated board was produced with different factors such as temperature of heated flutor; 27 °C, 160 °C, 180 °C and 200 °C, either using steam or non-stream.

The C-flute corrugation medium was then produced by using an optimum temperature of heated rollers and then supplied glue immediately. The gap between blade and roll was set in different level: 0.4, 0.7, 1 and 1.3 mm. The gap between gluing roller and pressure roller was set in various distances: 2.5, 3, 3.5 and 4 mm.

### 2.3 Analysis of Paper Qualities

The characteristic and properties of the produced corrugated board were determined and compared with the Thai Industrial Standard No. 550-2528 such as flute height, flute width, flute per meter, Burst Resistance, Flat crush resistance and Edge crush resistance. The satisfaction of machine model was evaluated by 3 technicians from corrugated board manufacturer using 5-scale questionnaire as a tool.

### 2.4 Analysis of Machine Characteristic

The electric power consumption, the productivity and the satisfaction of experts were then evaluated.

## 3. RESULTS AND DISCUSSION

### 3.1 Characteristic of Corrugated Board Making Machine

3.1.1 The flute forming unit is able to produce a C-flute Corrugation medium. The gear-like roll is 51.7 mm in diameter and 450 mm in length. The feeding table has a steaming unit that spray stream before the paper is fed to the roll of flutter. The heat of steel roll can be adjusted between 100 – 220 °C and this ability enhances the quality of flute setting by evaporation of moisture in the paper.

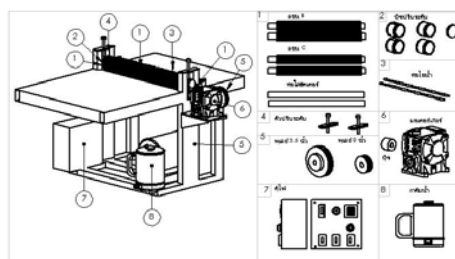


Fig. 2 The flute forming unit

3.1.2 The gluing unit is able to control the amount of glue supplied on the flute tips of corrugating medium by adjusting the gap distance between a gluing roller and a blade on the reservoir edge. The distance of a below pressure roller can also be adjusted. The paper sheet in the width of 19 inch can be fed into this machine.

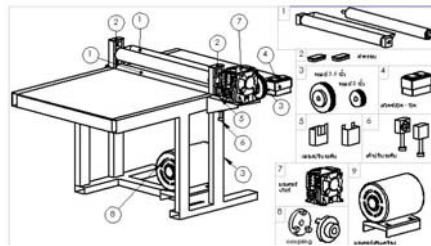


Fig. 3 The gluing unit

3.1.3 The liner laminator unit provides a pair of rolls that are adjustable for the gap distance according to the height of a Corrugated board. The maximum thickness for feeding is the double wall corrugated board or 5 plies.

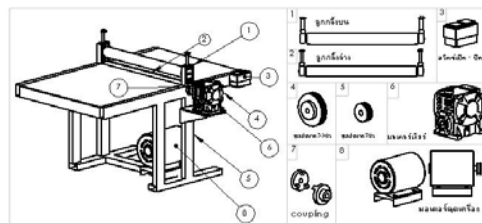


Fig. 4 The liner laminator unit

The constructed machine can produce a C-flute Corrugated board at the dimension of 297 x 420 mm per sheet with the production capacity of 5 sheets per minute.

### 3.2 Physical Properties of Corrugated Board

3.2.1 The physical properties of corrugating medium; height and width of a flute, forming by using temperatures of rollers at 27, 160, 180 and 200 °C with steam and non steam are shown in Table 1 and 2. The results showed that the increasing heat of roller made more flute height setting and the steam enhanced the quality of flute forming even though leaving for a long duration before lamination. In another way, if the flute height was increased, the flute width would be decreased. The optimum height and width of a flute were shown at 180°C which was lower economic power consumption in comparison to the heating the temperature of 200°C.

Table 1 The average of height (mm) of a C-flute on single face corrugated board.

	Non-steam				Steam			
	27 °C	160 °C	180 °C	200 °C	27 °C	160 °C	180 °C	200 °C
average	2.10	2.53	3.43	3.60	2.17	2.47	3.50	3.60
SD.	0.10	0.06	0.06	0.00	0.06	0.12	0.00	0.00

Table 2 The average of width (mm) of a C-flute on single face corrugated board.

	Non-steam				Steam			
	27 °C	160 °C	180 °C	200 °C	27 °C	160 °C	180 °C	200 °C
average	16.3	9.3	8.7	7.9	15.3	10.7	8.5	7.9
SD.	0.06	0.06	0.03	0.01	0.06	0.06	0.01	0.01

3.2.2 In the process of gluing, the C-flute corrugating medium forming at the optimum heated rolls of 180°C with steam was immediately applied the latex glue by adjusting different gaps of a glue blade: 0.4, 0.7, 1 and 1.3 mm. The distance between gluing roller and pressure roller were also adjusted in different levels: 2.5, 3, 3.5 and 4 mm.

**Table 3** The quality of corrugated board after applying glue.

Distance between pressure roller and gluing roller (mm)	Distance between gluing roller and blade of reservoir edge (mm)											
	0.4			0.7			1			1.3		
	Glue amount	Attachment	Board collapse	Glue amount	Attachment	Board collapse	Glue amount	Attachment	Board collapse	Glue amount	Attachment	Board collapse
2	little	bad	high	little	poor	high	enough	good	high	Too much	good	high
3	little	bad	medium	little	poor	medium	enough	good	medium	Too much	good	medium
3.5	little	bad	Low	little	poor	low	enough	good	low	Too much	good	low
4	little	bad	Low	little	poor	low	little	bad	low	little	bad	low

Table 3 shows that the best distance between gluing roller and blade of reservoir edge is 1 mm, because of the amount of glue supplying on the paper is enough. The best distance of a pressure roller and gluing roller is 3.5 mm because more distance between pressure roller and gluing roller resulted in less pressure apply on the corrugated board. In contrast, when the distance between pressure roller and gluing roller is too narrow, it will cause the flute collapse.

3.2.3 In the process of liner lamination, the corrugating medium, which was formed at 180°C with the steam system and immediately glued with optimum amount, was laminated with the liner to be a single face corrugated board by using a pair of pressing rollers. The gap distance between a top and a bottom rolls in liner laminator unit was adjusted at 2.5, 3, 3.5 and 4 mm.

**Table 4** Measurement of flute height (mm) with different distance between 2 rolls of the liner laminator unit.

Distance between a top and a bottom roll (mm)	Flute height (mm)		
	Before pressing	After pressing	Difference
2.5	3.81	2.76	1.05
3.0	3.80	2.96	0.84
3.5	3.82	3.33	0.49
4.0	3.81	3.80	0.01

The flute height (mm) was measured by the thickness of all plies minus to the thickness of liner papers. The result shows that the best distance between a top roll and a bottom roll of the liner laminator unit for a C-flute corrugated board should be 3.5 mm although it made a flute slightly collapse, however, its height remains under a standard range of C-flute (3.3-3.8 mm). The gap of 4.0 mm is not good because it provided too less pressure for line lamination.

3.2.4 The physical properties, such as flute height, flute width and number of flute per meter, of the produced C-flute corrugated board at the optimum factors were shown in Table 5. The results were also compared with the commercial corrugated board and the Thai Industrial Standard No. 550-2528.

The result in Table 5 shows that a C-flute corrugated board produced from the model machine created the acceptable character compared to the standard. However, the produced flute tips had V-shape while the standard has U-shape because the gear-like rolls using milling process had the V-shape pitch. The width of the C-flute is slightly narrower than the standard, but it can be adjusted by reducing the flute height.

**Table 5** The physical properties of corrugated board.

Type of Corrugated Board	Height (mm)	Width (mm)	Number of flute per meter	Take-up factor
Produced C-flute Corrugated Board	3.8	7.5	142	1.42
Commercial C-flute Corrugated Board	3.7	7.9	140	1.4
TIS. No. 550-2528	3.6 ± 0.25	7.9	140 ± 5	1.42

3.2.5 The physical properties, such as burst resistance, flat crush resistance and edge crush resistance were shown in Table 6. The tests show that the burst resistance of produced C-flute corrugated board was better than the commercial C-flute corrugated board because the type of latex glue that has a better flexibility than the natural glue, which is used in the commercial industry.

**Table 6** The burst resistance, flat crush resistance and edge crush resistance of the C-flute corrugated board.

Temperature used to create flute 180 °C	Without steam	With steam	Commercial C-flute
	$\bar{X}$	$\bar{X}$	
Bursting Resistance (kPa)	1093.10	1093.87	776.83
Flat Crush Resistance (N)	861.5	631.67	1,966.67
Edge Crush Resistance (N)	383.33	390.50	356.00

The result shows that the flat crush resistance of produced C-flute corrugated board was poorer than the commercial C-flute corrugated board. The corrugated board produced from the model machine provided less flat crush resistance because more flute height and V-shape flute provide less area for pressure resistance. Therefore, less pressure applies to the surface area will cause the flute collapse easier than the factory made corrugated board. The corrugated board produced in the factory gave less edge crush resistance than the produced corrugated board, meaning that it was acceptable.

### 3.3 Characteristic of Corrugated Board Making Machine

#### 3.3.1 Electric Power Consumption

Each unit of the corrugated board making machine used 220 V. The flute forming unit was consisted of electric motor that used 200 W, boiler used 650 W and heater in 2 fluting rollers used 500 W per roller. Total electric power of the flute forming unit was then 1,850 W. The electric motor of gluing unit used 200 W and the liner laminator unit used 200 W. Therefore, total electric power of this corrugated board making machine was 1,850 + 200 + 200 = 2,250 W or 2.25 kW.

#### 3.3.2 Productivity

The productivity of the corrugated board making machine was about 1 minute per 10 sheets of single-wall corrugated board sized of 297 x 420 mm.

#### 3.3.3 Evaluation of Satisfaction

The machine model was evaluated for the qualities and the satisfaction by three experts from the corrugated board manufacturer. The 5-scale questionair was used as a tool. The average score of satisfaction on machine structure design, application and characteristic was 4.25, meaning that design and function is good. For the produced corrugated board, the average score was 4.25, meaning that the experts was satisfied in the corrugated board production.

#### 4. CONCLUSION

In conclusion, the corrugator machine that was constructed for use in the paper laboratory can produce the C-flute corrugated board with the V-shape flute. The overall character and physical properties of the produced corrugated board was acceptable compared to the Thai standard of corrugated board TIS. No. 550-2528. The satisfaction evaluation on the structure design, application, characteristic and production of the machine indicated a good level. Therefore, the corrugator model machine can be applied to make the corrugated board from different types of paper not only to produce corrugated box, but also crusing packaging, fancy art paper and many other purposes.

#### ACKNOWLEDGMENT

The author would like to thank The Graduates and International Office, King Mongkut's University of Technology Thonburi for the financial support. Many appreciation are due to Machinery Emporium (1995) CO., LTD. for support equipments and place in the construction of machine model, and Kookiat Lonkradad CO., LTD. for donation of the craft papers for corrugated board producing.

#### REFERENCES

1. Robert R.A.Higham, 1971, **A HANDBOOK OF PAPERBOARD & BOARD Volume 2**, Mercury House, Waterloo Road, London, pp. 101-155.
2. Jame E. Kline, 1991, **Paper and Paperboard Manufacturing and Converting Fundamentals Second Edition**, Miller Freeman Publication, INC, New York, pp. 184-194.
3. APPI PRESS, 1991, **TAPPI TEST METHODS 1991 VOLUME ONE** , Fibrous Material and Pulp Testing T1-T270 and Paper & Paperboard Testing T400-T550,USA
4. Tomas Nordstrand, 2004, **Analysis and testing of corrugated board panels into the post-buckling regime**, Composite Structures Volume 63, Issue 2, Pages 189-199.
5. P. Isaksson, A. Kruser. And P.A. Gradin, 2007, **Shear correction factors for corrugated core structures**, Composite Structures Volume 80, Issue 1, Pages 123-130.