CUTTING TECHNOLOGY OF AUTOCLAVED CELLULOSE FIBRE REINFORCED CEMENT BOARD

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ABSTRACT

There are various types of cutting technologies of cellulose fibre reinforced cement board. In order to get a prefect cutting in term of appearance and dimension, normally it involves two stages of cutting, wet cut and dry cut. Wet cut is the cutting done during the green fibre cement sheets produced by the Hatschek machine and dry cut is conducted after the sheets are cured by autoclaving.

This paper presented a study done to eliminate the dry cutting process in order to reduce the operating cost, improving the productivity and conserve the environment by not generating dust while providing the good cutting quality. The presentation provides improvement factors, problems faced of water-jet cutting methodology on autoclave cellulose fibre reinforced cement boards.

KEYWORDS:

Fibre Cement; Cellulose Fibre; Autoclave; Cutting.

INTRODUCTION

A typical manufacturing process of autoclaved cellulose fibre reinforced cement board is shown in Figure 1.

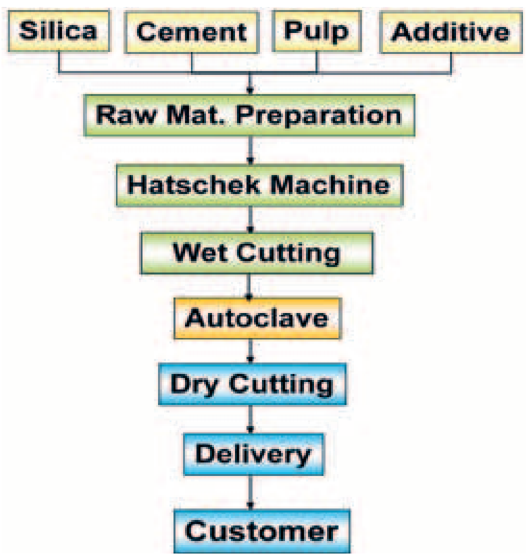


Figure 1 – Autoclave Cellulose Reinforced Fibre Cement Manufacturing Process Flow

As shown in the process flow, there are 2 stages of cutting, wet cutting and dry cutting. Wet cut is the cutting done for the green fibre cement sheets produced by the Hatscheck machine and dry cut is conducted after the sheets are cured by autoclaving. The dry cut is basically a trimming process in order to achieve the exact sheet dimensions based on the customer requirements and also to have a good cut edges appearance. The dry cutting process consumes almost 10% of the manufacturing cost. It involves 50% of the total production workforce. Besides, the diamond blades used for the dry cutting are costly and requires well maintenance. There is also the off-cut or trimming waste of about 4% of the board materials generated and this incurred the waste disposal cost. Furthermore, the working environment is relatively dusty where huge dust collector systems have to be employed. Without the dry cutting, no doubt, the productivity will be increased tremendously, the operating cost will be definitely reduced and more importantly, we will have the conducive working environment.

The objective of this study is to eliminate the dry cutting process by introducing a well established wet cutting system. Water-jet cutting technology is the wet cut methodology that we explore here. The main outcomes that we want to achieve are to obtain the acceptable quality on cut edge appearance and also the exact finished products' dimensions by using water-jet cutting.

Water-jet cutting system (refer Figure 2) was studied instead of other wet cutting method such as stamping press and circular saw because of the advantages that we foresee as listed in the Table 1 below:

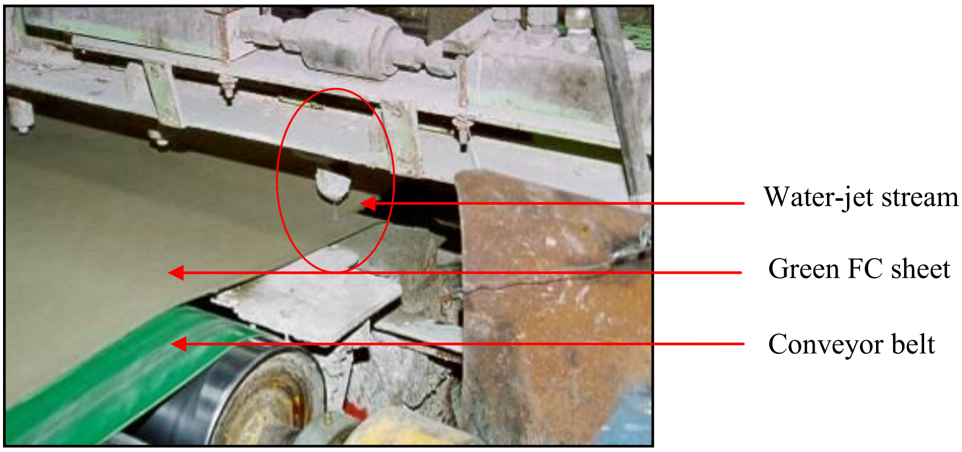


Table 1 – Advantages & Disadvantages of Various Wet Cutting System

Type of Cutting System	Water-jet	Circular Blade	Stamping Press
Productivity	High	Medium	Low
Sheet Dimension Tolerance	Medium	Medium	Good
Sheet De-lamination	No	Possible	Possible
Clean Cut (no burr / wet chips)	Yes	No	No
Edge Appearance	Medium	Medium	Good
Cost of Maintenance	Medium	High	High

STUDIES

Series of studies been done to determine the factors that contribute to the efficiency and effectiveness of the water-jet cutting system. The challenges of the study are
(a) How to achieve the good cut edge appearance, i.e. approaching the dry saw cutting (refer Figure 2)?
(b) How to achieve the good dimension tolerance for the cut sheet?
(c) What will be the dimensions' changes after the autoclaving process?

Figure 3 – Dry Saw Cut Edge Appearance

Edge Appearance

Few factors that might contribute to the quality of edge appearance after water-jet cut have been studied. The factors such as

1. Water-jet pressure
2. Nozzles diameter
3. Material fineness
4. Conveyor speed

Water-jet Pressure

From the cutting or hydraulic power calculation shown in Table 2 below, water-jet pressure contributes to the cutting power. The higher is the pressure, the higher the cutting energy. However, higher pressure always incurs higher investment and operating costs. Therefore, optimum pressure for the cutting system is required. A study on water-jet working pressure from 10kpsi to 30kpsi was conducted. Fibre Cement green sheets with 7.5mm thickness as the cut specimens. From the findings, refer Figure 4, it showed pressure $\geq$ 25 kpsi have less protruded or dented lines (circle area) at the edges comparing to lower pressure. The pressure at 10kpsi was not able to cut through the green sheet during this experiment.

Table 2 – Water-jet Cutting Power Calculation

Imperial Unit	Metric Unit
$\text{Cutting Power (hhp)} = \dfrac{\text{Pressure(psi)} \times \text{Flow Rate(gpm)}}{1715}$	$\text{Cutting Power (hKW)} = \dfrac{\text{Pressure(bar)} \times \text{Flow Rate(lpm)}}{600}$

Figure 4 – Cut Edge Appearance – Effect of Working Pressure

Nozzle Diameter

Water flow rate plays an important role of the cutting power; refer Table 2 above for the cutting power calculation. Higher flow rate is preferable in order to provide higher cutting energy. The rate of water discharged from nozzle depends on the water pressure and also the nozzle orifice diameter. Bigger nozzle's diameter provides higher water flow rate generally. The objective of this study is to determine the suitable diameter of the nozzle which can be used to achieve better cutting edge.

Sapphire orifice nozzles were used for this study, refer Figure 5. Before the experiment conducted, we must know the maximum flow that nozzle can receive in the cutting system. This was done by dividing the maximum flow rate (gpm) that the pump motor can deliver with number of nozzles that are going to be used in the cutting. Then, we must determine which working pressure that we intended to operate. From the Nozzle Flow Chart as example shown in Figure 6, we know which nozzle orifice diameter that we can apply in order to get the highest cutting power theoretically. The effect of the nozzle diameter and cutting power to the cut edge appearance was then proven by conducting the practical experiments.

The experiment conducted based on the water pressure and nozzle size as stated in Table 3. 0.20mm versus 0.30mm nozzle orifice diameter was studied. Besides, 25Kpsi versus 35Kpsi working pressure were evaluated simultaneously in the experiment. Cutting powers were calculated for each set of test. The maximum water flow rate of the water-jet pump was 4gpm. Thus, in order to operate the system, the total flow rate of the nozzles used must below this value.

Figure 7 displayed the results of the experiment and it was clearly showed that with higher pressure, 35Kpsi and bigger nozzle orifice diameter, 0.30mm which generated higher cutting power has the best cut edge appearance while 0.20mm nozzle diameter with 25Kpsi pressure has the worst cut appearance.

Figure 5 - Sapphire Orifice Nozzles

NOZZLE FLOW CHART (THEORETICAL)

FOR NLB 0° SAPPHIRE ORIFICE NOZZLES - GPM *(LPM)*

PRESSURE PSI *(BAR)*

BN3539	20,000 *(1,400)*	22,000 *(1,520)*	24,000 *(1,655)*	25,000 *(1,725)*	26,000 *(1,800)*	28,000 *(1,930)*	30,000 *(2,070)*	32,000 *(2,210)*
-6	0.11 *(0.42)*	0.11 *(0.42)*	0.12 *(0.45)*	0.12 *(0.45)*	0.12 *(0.45)*	0.13 *(0.49)*	0.13 *(0.49)*	0.14 *(0.53)*
-7	0.15 *(0.57)*	0.15 *(0.57)*	0.16 *(0.61)*	0.17 *(0.64)*	0.17 *(0.64)*	0.17 *(0.64)*	0.18 *(0.68)*	0.19 *(0.72)*
-8	0.19 *(0.72)*	0.20 *(0.76)*	0.21 *(0.79)*	0.22 *(0.83)*	0.22 *(0.83)*	0.23 *(0.87)*	0.24 *(0.91)*	0.24 *(0.91)*
-9	0.24 *(0.91)*	0.26 *(0.98)*	0.27 *(1.02)*	0.27 *(1.02)*	0.28 *(1.06)*	0.29 *(1.10)*	0.30 *(1.14)*	0.31 *(1.17)*
-10	0.30 *(1.14)*	0.32 *(1.20)*	0.33 *(1.25)*	0.34 *(1.28)*	0.34 *(1.30)*	0.36 *(1.35)*	0.37 *(1.40)*	0.38 *(1.45)*
-11	0.37 *(1.38)*	0.38 *(1.45)*	0.40 *(1.51)*	0.41 *(1.54)*	0.42 *(1.58)*	0.43 *(1.64)*	0.45 *(1.70)*	0.46 *(1.75)*
-12	0.43 *(1.64)*	0.46 *(1.73)*	0.48 *(1.80)*	0.49 *(1.84)*	0.50 *(1.87)*	0.51 *(1.95)*	0.53 *(2.01)*	0.55 *(2.08)*
-13	0.51 *(1.93)*	0.54 *(2.03)*	0.56 *(2.11)*	0.57 *(2.16)*	0.58 *(2.20)*	0.60 *(2.28)*	0.62 *(2.36)*	0.65 *(2.44)*
-14	0.59 *(2.24)*	0.62 *(2.35)*	0.65 *(2.45)*	0.66 *(2.50)*	0.67 *(2.55)*	0.70 *(2.65)*	0.72 *(2.74)*	0.75 *(2.83)*
-15	0.68 *(2.60)*	0.71 *(2.70)*	0.74 *(2.82)*	0.76 *(2.87)*	0.77 *(2.93)*	0.80 *(3.04)*	0.83 *(3.15)*	0.86 *(3.25)*
-16	0.77 *(2.92)*	0.81 *(3.07)*	0.85 *(3.20)*	0.86 *(3.27)*	0.88 *(3.34)*	0.91 *(3.46)*	0.95 *(3.58)*	0.98 *(3.70)*
-17	0.87 *(3.30)*	0.92 *(3.46)*	0.96 *(3.62)*	0.98 *(3.69)*	0.99 *(3.76)*	1.03 *(3.91)*	1.07 *(4.04)*	1.10 *(4.18)*
-18	0.98 *(3.70)*	1.03 *(3.88)*	1.07 *(4.05)*	1.09 *(4.14)*	1.12 *(4.22)*	1.16 *(4.38)*	1.20 *(4.53)*	1.24 *(4.68)*
-19	1.09 *(4.12)*	1.14 *(4.33)*	1.19 *(4.52)*	1.22 *(4.61)*	1.24 *(4.70)*	1.29 *(4.88)*	1.33 *(5.05)*	1.38 *(5.22)*
-20	1.21 *(4.57)*	1.27 *(4.79)*	1.32 *(5.01)*	1.35 *(5.11)*	1.38 *(5.21)*	1.43 *(5.41)*	1.48 *(5.60)*	1.53 *(5.78)*

Figure 6 - Nozzle Flow Chart

Table 3 – Working Pressure, Nozzle Diameter and Cutting Power Study

Test	Pressure, Kpsi	Nozzle Type	Nozzle Diameter, mm	Flow Rate/ Nozzle, gpm	No. of Nozzles used	Total Flow Rate, gpm	Cutting Power / nozzle, hhp
Test 1	25	#8	0.20	0.22	6	1.32	3.21
Test 2	25	#12	0.30	0.49	6	2.94	7.14
Test 3	35	#8	0.20	0.26	6	1.56	5.31
Test 4	35	#12	0.30	0.58	6	3.48	11.84

Material Fineness

The appearance of protruded and dented area at the edges were suspected causing by the availability of rough materials. Sand is one of the major raw materials of autoclaved fibre cement sheet. The amount in the recipe is huge, i.e. more than 55%. The raw sand from mining source normally goes through the ball milling process before subjected to the mixing slurry process. It is interesting to know the effect of ground sand fineness to the cutting appearance. An experiment was done by making fibre cement sheets with selected sand fineness as shown in Figure 8. The finding showed obviously that the acceptable cut edge appearance was achieved by using sand with fineness below 125 micron, preferably 45 micron and below.

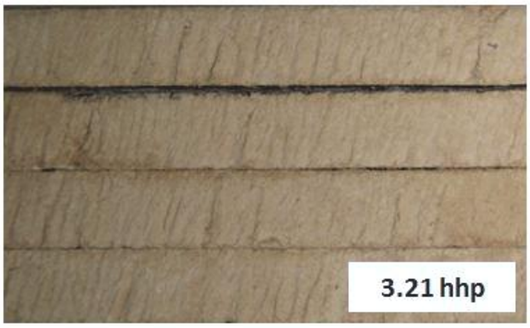
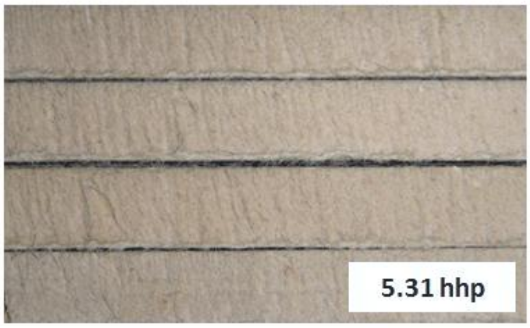
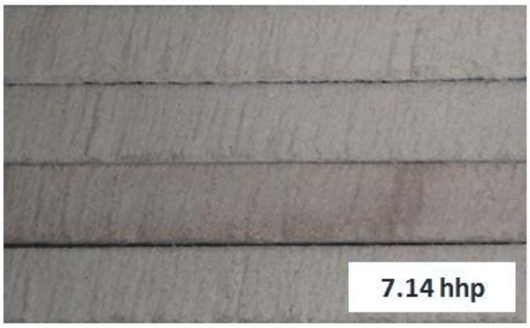
Nozzle Size (mm)	Pressure (Kpsi)	
	25	35
0.2		
0.3		

Figure 7 – Cut Edge Appearance – Effect of Pressure, Nozzle Diameter and Cutting Energy

Figure 8 – Cut Edge Appearance – Effect of Sand Fineness

Conveyor Speed

The water-jet cutting speed depends on the conveyor moving speed. A study to investigate whether the speed is the factor that contributes to the cutting appearance was conducted. Conveyor speed set at 40m/min, 45m/min, 50m/min, 55m/min and 60m/min were studied. The findings as shown in Figure 9 indicated that there was no significant difference on the cut appearance within these ranges of conveyor speeds or cutting speed. Theoretically, slower speed is preferable to have a nice cutting; however, it will slow down the productivity.

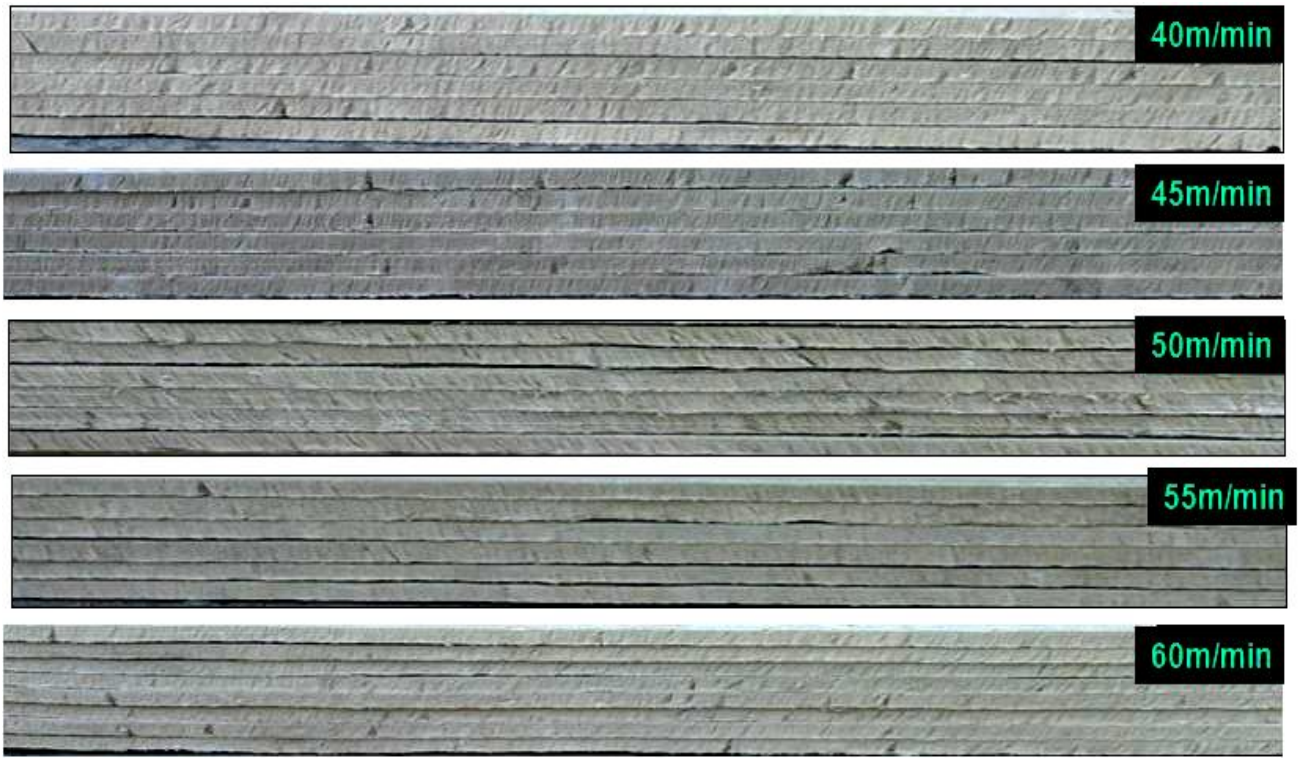


Figure 9 – Cut Edge Appearance – Effect of Cutting Speed

Sheet Dimensions

Another quality that we consider for water-jet cutting system is the sheet dimensions which include straightness, squareness (diagonal differences), length and width tolerance.

To achieve the straightness and squareness as what the dry cutting has is a huge challenge. The straightness and squareness of the sheet are very much depending on the alignment of the Hatsheck machine and the conveyor system. To avoid any drifting of the fibre cement green sheet during movement, it is good to have the water-jet locating at the end of the conveyor system before the stacker. This is practised especially for along edge cutting. Typically the green sheets are moving while the water-jets are stagnant for the along cut. For cross cut, it is done at the stacker area where there is no movement of the green sheet. Table 4 below shows the straightness and squareness achieved by water-jet cutting comparing with dry cutting.

The length and width tolerances of water-jet cut generally higher as compared with the dry cut, refer Table 4.

Table 4 – Dimensional Tolerance Comparison

Parameters	Water-jet Cut	Dry Saw Cut
Straightness tolerance, mm	0 - 2	0 - 1
Squareness tolerance, mm	0 - 3	0 - 2
Length tolerance, mm	0 - 4	0 - 2
Width tolerance, mm	0 - 3	0 - 2

As a result, there is still a challenge and room of improvement for water-jet cut to achieve the dimensional tolerance as dry cutting.

Dimension Change after Autoclave

Studies were done to determine whether there is any expansion or contraction of the green sheets after autoclaving. Series of length and width measurements were done for various fibre cement products and with different sizes. The length of the 4 edges of fibre cement sheets (refer Figure 10) were measured before and after the autoclaving process. The finding showed that there was length shrinkage of the fibre cement sheets after autoclaved. The shrinkage values were various, from zero shrinkage up to 4mm as shown in Table 5. Figure 11 showed the monitoring chart of one of the fibre cement products length and width measurements before and after autoclaving.

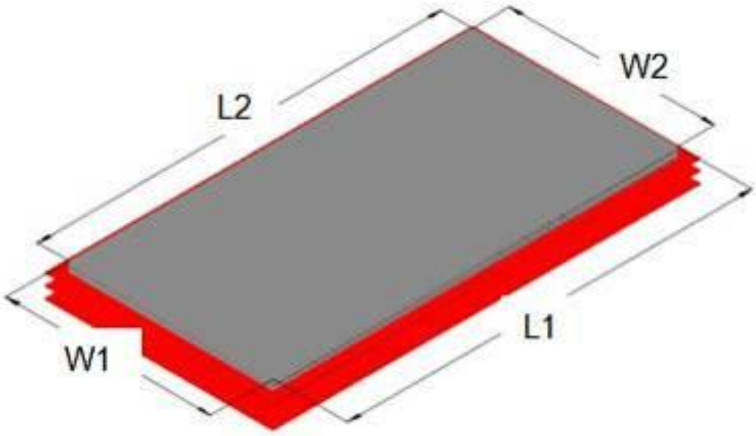


Figure 10 – Dimensional Measurements for 4 edges of FC sheet

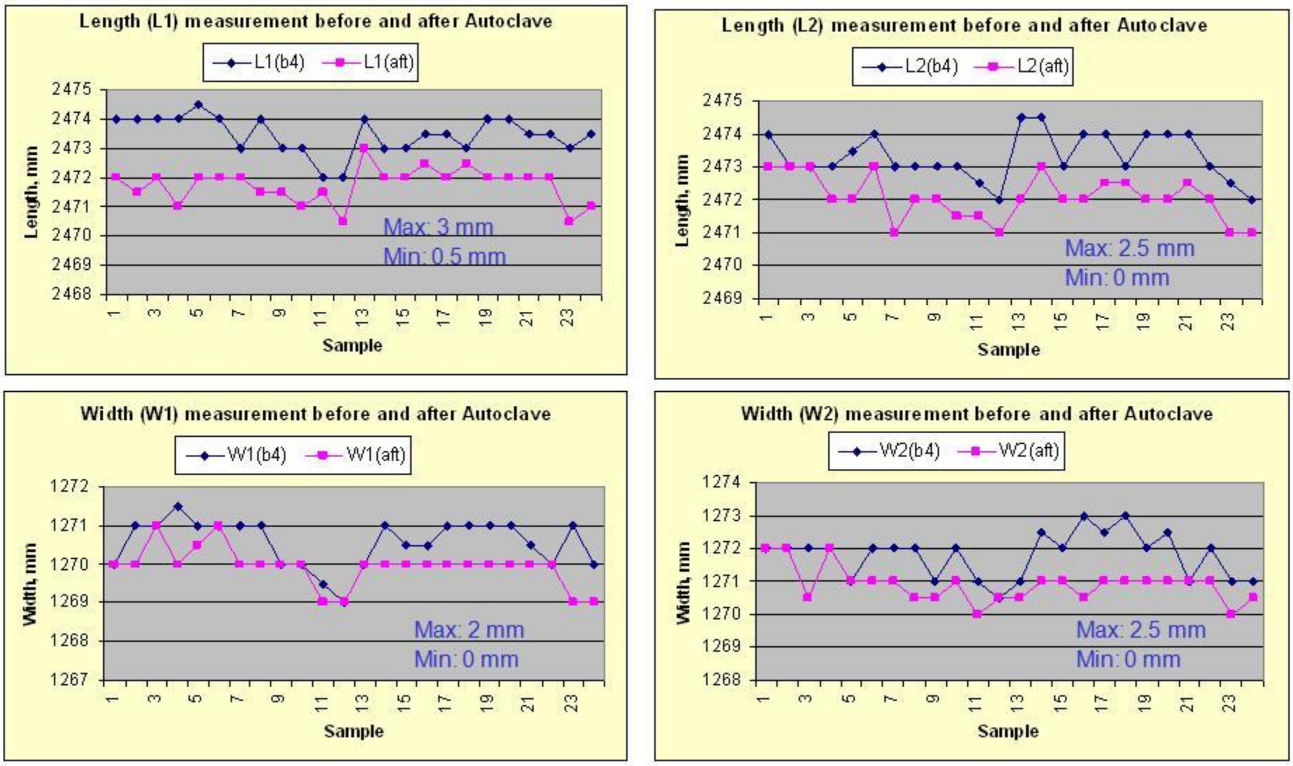


Figure 11 – Charts showing the Dimensions Before and After Autoclave

Table 5 – Maximum & Minimum Shrinkage of Each Dimension of Various Products

K1		Length 1 (mm)		Length 2 (mm)		Width 1 (mm)		Width 2 (mm)	
Product WxL (mm)	Thickness (mm)	Max	Min	Max	Min	Max	Min	Max	Min
A - 1230x2430	6	3	0	3	0	3	0	2.5	0
B - 1270x2470	3.2	3	0.5	2.5	0	2	0	2.5	0
C - 1230x2730	4.5	2	0	2	0	1	0	1	0
D - 1230x2430	12	2	0	1	0	2	0	2	0
E - 209x3700	7.5	3	0	3.5	0	1.5	0	1	0
F - 1230x2430	6	2	0	2	0	1	0	1.5	0
G - 960x4300	6	4	1	4	1	1	0	1	0
H - 920 x 1830	6	2	0	2	0	1	0	1	0
I - 1240 x 2460	3.2	3	1	3	1	2	1	2	1
J - 1240x 2460	4.5	2	0	2	0	1	0	2	0

Again, this is a bigger challenge for us on how to control the dimensional contraction after autoclaving. We would prefer a consistent shrinkage instead of the various shrinkages which we found from the experiments. It is difficult for us to achieve our end products with length and width tolerance at maximum 2mm that desired by most of our customers.

There are two factors that may contribute to the dimensional change:

(a) Chemical movement – the product formulations, the stability of the raw materials, the chemical reaction during autoclaving. This is somehow difficult to control.

(b) Physical movement – environment condition (temperature & humidity), water content of the green sheet and mechanical transportation or loading. We can eliminate this factor by control and ensure these parameters consistent at all time.

Future works are required to solve this in-consistent contraction issue.

CONCLUSION

In order to achieve better cut edge quality, means no prominent jagged lines, no burr or shape edges, high water-jet pump pressure and big nozzle diameter (increase flow rate) are needed. Both these parameters contribute to the high cutting energy. The higher the cutting energy, the more effective and efficient of the water-jet cut system. However, high pump pressure normally incurs a higher investment and operating costs. As a result, we have to determine the optimum pressure that we require and type of water-jet system that we need based on the cost benefit analysis.

Material fineness also influences on the cut edge appearance and it is good to have very fine materials in the mixing slurry. Again, the cost and process control will be the determining factors.

The straightness and squareness tolerance of the water-jet cut sheets are not as good as dry cutting, refer Table 4. However, the tolerances meet most of the fibre cement product standards. Further improvement activities are required to close the gap if the tight tolerance is required by the customers.

Besides, further investigation is required to determine the root causes of the deviations and inconsistency in sheet shrinkage that occurred after the autoclave curing. This issue must be solved in order we can totally eliminate the dry cutting process.