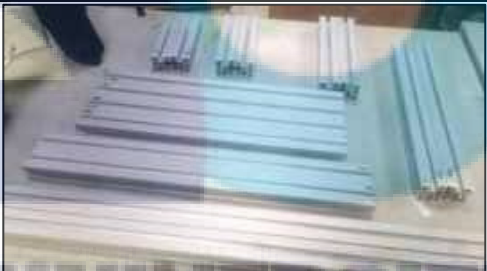


CHAPTER 4 - RESULT AND DISCUSSION

4.1 Mechanical Result

Every development of building the *nata* cutting machine are listed in the table below, sorted by the timeline.

Table 4.1 – Components Bought or Fabricated

Num.	Date	Component Description	Picture(s)
1	21 st January	Machine Bed from AR Lasercut	
2	26 th January	Aluminum Profiles from Infiniti Group Indonesia picked up in Cikupa and then fabricated	
		Aluminum Profiles assembled into structure	
3	7 th February	Acrylic Parts and Glue bought	

4	15 th February	Machine Bed already assembled and the protective stickers are peeled off	 
5	24 th February	IGUS Linear Guide samples	
		IGUS Linear Guide bought and additional Acrylic Parts bought	 
6	12 th March	Clamp with slits is machined using conventional milling machine	

6	12 th March	Clamp with slits is machined using conventional milling machine	
7	17 th March	Pneumatic System piping and valves designed, assembled, and integrated into the machine	  
8		Clamping Module assembly and post-processing	 

8	17 th March	Clamping Module assembly and post-processing	
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After all of the components are assembled, on 4 April 2017, the completely assembled *nata* cutting machine is ready for doing the designated tests.



Figure 4.1 – Finished *nata* cutting machine: (a) the whole machine, (b) clamping module close up, (c) blades close up.

4.2 Electrical Result

4.2.1 Safety Technic

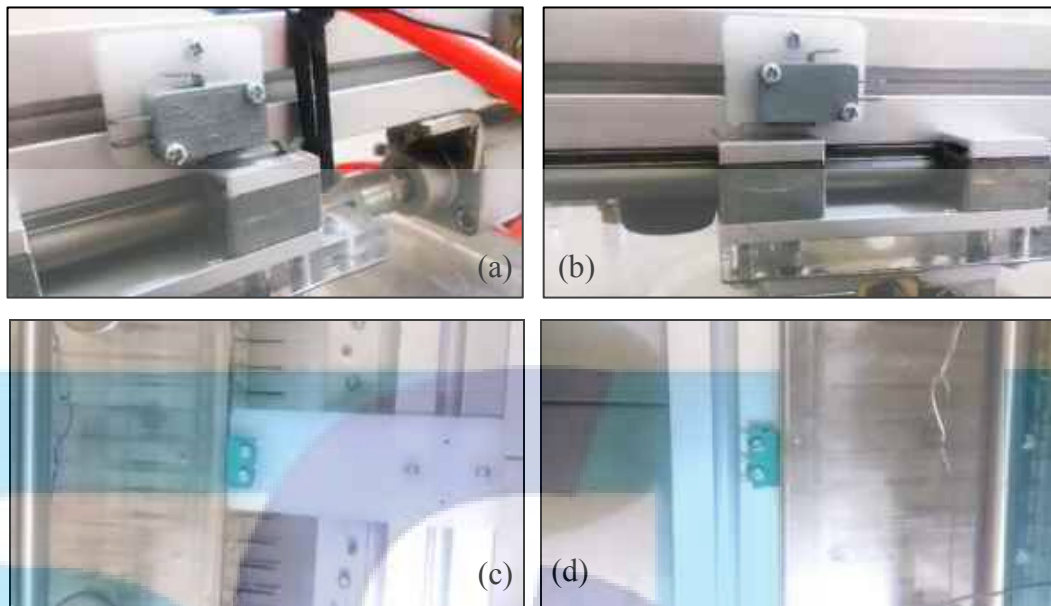


Figure 4.2 – Limit switches in 4 positions, (a) initial X-cut, (b) final X-cut, (c) initial Y-cut, and (d) final Y-cut

Referring to the Chapter 3.6.1 above about Safety Measures, four limit switches have been placed onto the machine within the designated area as seen in the Figure above. It is also stated above that solenoid valves will be involved into the Safety Control Logic3.6.3. The Safety Control Logic itself must be made into PLC Program.

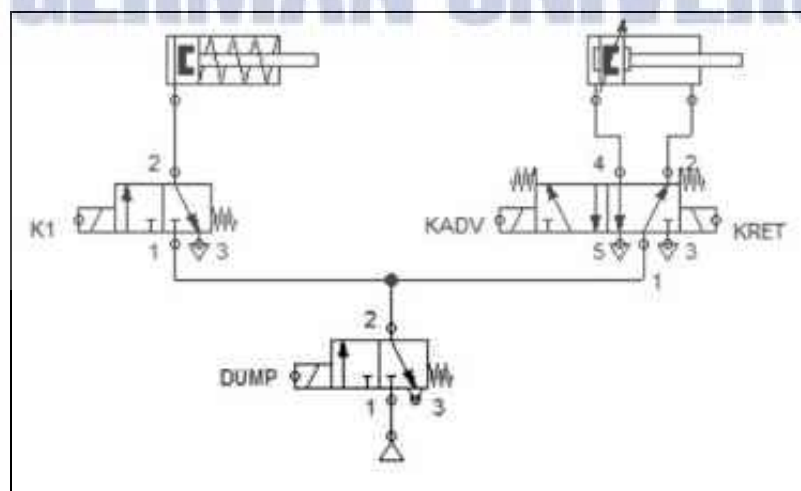


Figure 4.3 – Solenoid Valves and actuator simulation

Before making the real PLC program, a simulation before is necessary. The simulation also has to simulate the actuator reaction from given condition. Therefore, a simulation program, which can simulate both the pneumatic and electrical logic, is selected, as shown in appendix C.1. **Logic Simulation Using FluidSIM.**

4.2.2 PLC Program

A PLC program is made using Totally Integrated Automation Portal or TIA Portal, in short, a program to build a PLC program from Siemens. The complete PLC Program can be seen in appendix C.2. **Final PLC Program.**

4.2.3 Control Panel

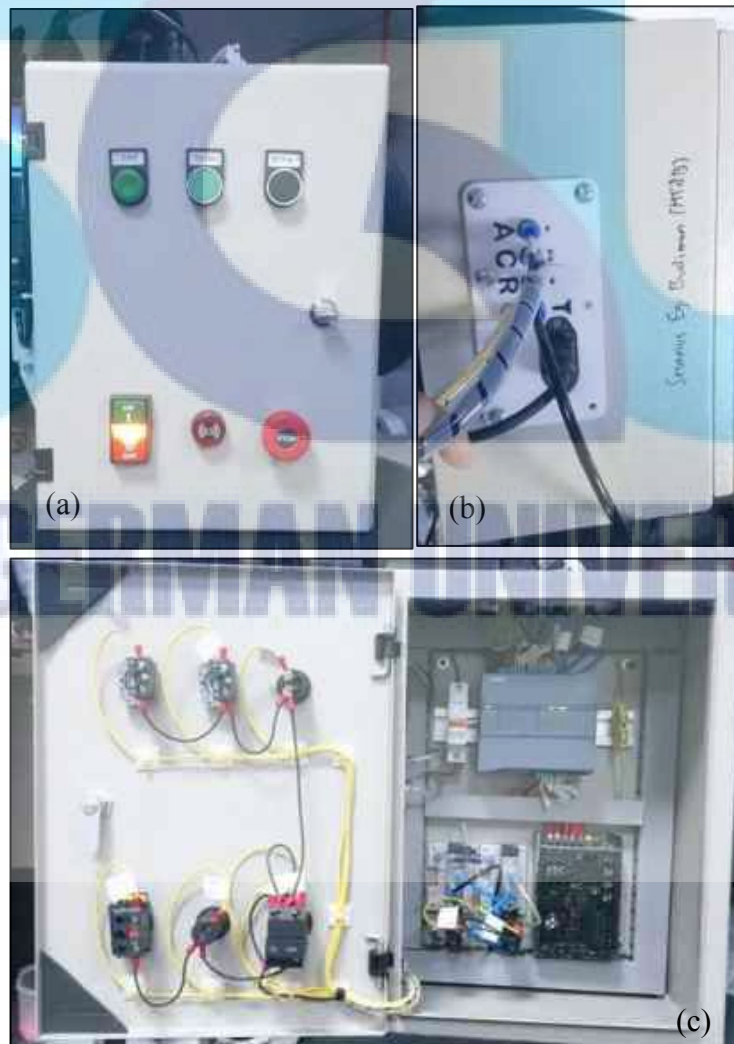


Figure 4.4 – Control panel result (a) front view (b) top view, and (c) inside view

A control panel is made with complete wiring, a circuit breaker, grounding terminal, railings, ducting, power supply, power plug, and so on. The control panel also covers

for all pneumatic valves. The inputs of the control panel are only AC power plug and an air source for the pneumatic system. A DB9 cable is also used for signal exchange between the solar panel with the machine (for all limit switches and collision detection sensor).

4.2.4 Collision Detection

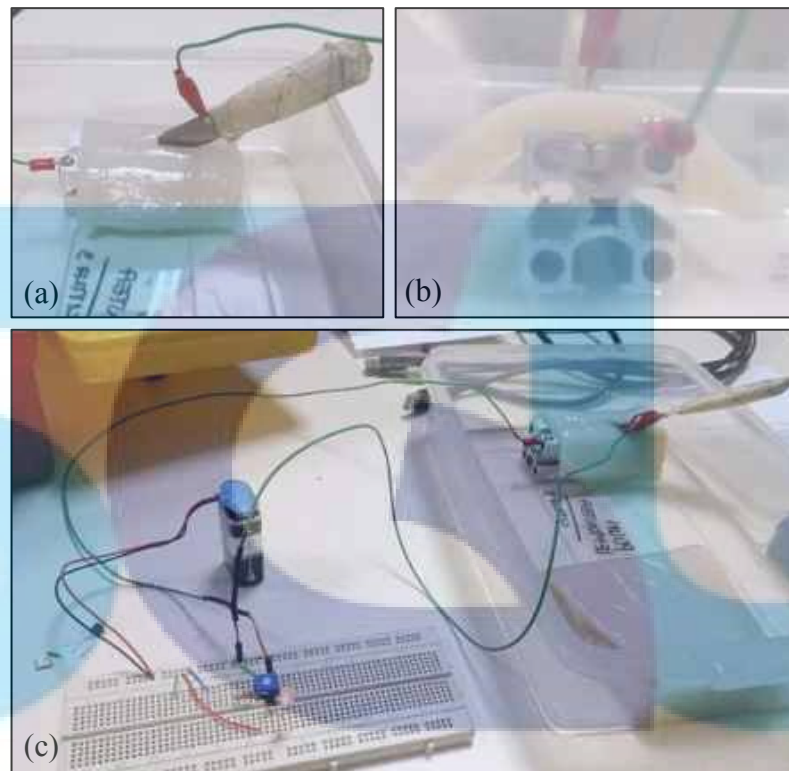


Figure 4.5 – Collision detection test (a) side view (b) front view (c) with proto board

A collision detection test has been conducted by the researcher. However, the schematic did not work as intended. When the blade touches nata only, the LED is ON, but when the blade touches the aluminum profile (as a representation of the clamp), the LED goes OFF. It is exactly the opposite of the initial intended design.



Figure 4.8 – The result for clamping mechanism: (a) initial, (b) advances, (c) final

The cylinder advances very well and very fast without any collision. However, the custom adapter for between the linear guides, which connects the clamp with X-cut cylinder piston rod, cracks instantly on the first try.

4.3.2 Discussion

The clamp cannot be retracted automatically even if springs already implemented. It is expected a spring return condition will happen. Due to the manufacturing is not precision, the tolerances between the top part of the clamp and the bottom side are very poor, thus resulting in a great deal of friction between the bolt stopper and the clamp wall, which cannot be fought using small springs.

The custom adaptor cracks instantly due to the momentum of the clamp. The movement was very fast and the clamp itself, after embedded with a pneumatic system, weighs too high. Moreover, there is no stopper whatsoever which can absorb the momentum. Not to mention, the custom adapter is made out of acrylic, which is very brittle. Heavy weight, high velocity, no stopper, and the acrylic material is not a good combination.

4.3.3 Revision

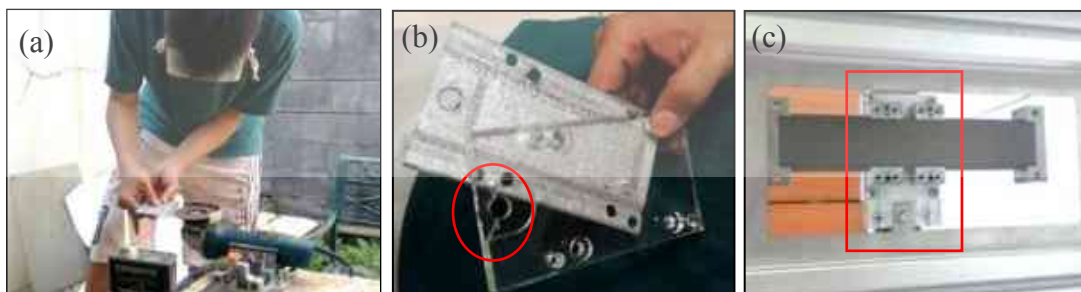


Figure 4.9 – The solution: (a) in fabrication, (b) result, (c) implemented

The solution for the broken adaptor is to strengthen it using metallic material support. There is an unused galvanized steel beam that can be made into the support. In Figure

4.7b, the red circle shows the crack in the acrylic after gluing. In Figure 4.7c, the support has been implemented into the linear guide adaptor.

4.4 First and Second Test

The first test is conducted on 2 April 2017 and continued (considered as Second Test) on 5 April 2017. The purpose of the test is testing both X cut and Y cut using *nata* sheet sample.

4.4.1 Result

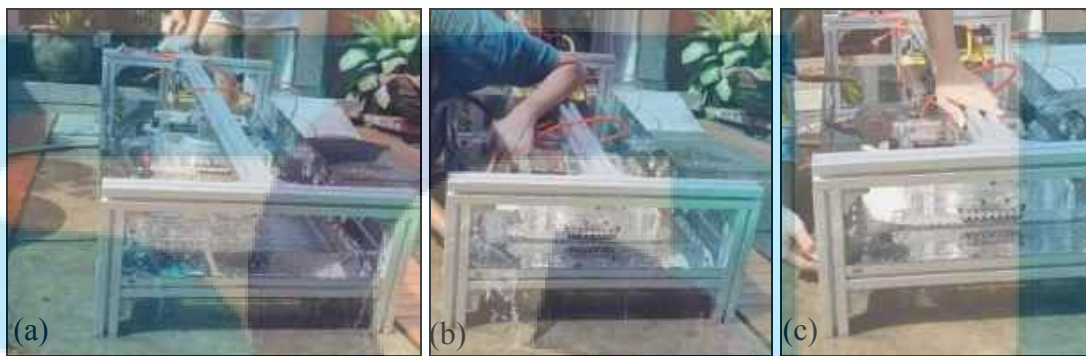


Figure 4.10 – First testing (a) X-cut, (b) Y-cut, (c) result.

The testing on 2 April 2017 is conducted 3 times, and no three of them is good because the clamp is not “clamping” enough. The *nata* always come along with the blades.

Table 4.2 – First Testing Summary

Result	Potential Root Cause	Action Plan
20% X Cut 45% Y Cut 0% X Complete Cut 0% Y Complete Cut The nata sheet is left behind	Clamp not low enough	Clamp height is lowered



Figure 4.11 – The sample soaked in water to soften the texture

For the testing on 5 April, the sample *nata* is soaked in the water first before being cut. This is to remove the acidic preservatives which make the nata tend to be denser. It is expected that the osmotic phenomenon can soften the sample and makes it more alike with the commercial product often found in mini markets.



Figure 4.12 – Second test result photos

All *natas* are still being dragged by the blade. However, the results suggested that the method is legit because it still can make square cuts even though the *natas* are dragged along.

4.4.2 Discussion

From the testing results above, it can be concluded that the clamping surface is uneven because sometimes it cuts well; sometimes some part of the sample is dragged along. The blades sharpness also has an influence. The result of the cut is not cubic; it is more like half circles. These mean the *nata* are being compressed rather than cut.

A simulation is done to check the blade sharpness. The researcher takes out the blades set and try to cut another material, in this case, jelly. It turns out; the researcher requires somewhat big force for cutting a jelly. From this simulation, it is concluded that the blades must be changed into something sharper.

For the clamping problem, a simulation via SolidWorks is made. The original design was using 10 millimeters thick acrylics as the clamp surface. The maximum deviation when being pressurized by two bars is 5 mm.

Table 4.3 – Second Testing Summary

Result	Potential Root Cause	Action Plan
60% X Cut 80% Y Cut 0% X Complete Cut 7% Y Complete Cut The result is 	Blades not sharp enough Clamp too weak	Change blades Change clamp

4.4.3 Revision

For the clamp problem, the material is interchanged from acrylic to aluminum. When using aluminum, the maximum deviation when pressurized with two bars is only 0.2 mm. The clamp design then subbed out to be CNC-milled.



Figure 4.13 – The new clamp made out of aluminum

Because the clamp is now made out of aluminum, the momentum should have gone much bigger, since the mass of the clamp itself has been quadrupled than before. Therefore, a rubber stopper is now installed to absorb the momentum.



Figure 4.14 – Rubber door stopper to absorb the momentum

For the blades problem, the blades are changed into the paper cutter, just like The Apparatus from Chapter 3.7 Preliminary Concept Testing. The property of food safety has to be neglected to achieve the blade sharpness of a paper cutter.



Figure 4.15 – The blades are (a) changed into paper cutters with (b) new jigs



4.5 Third Test

The third test is conducted on 19 May 2017. The clamp is now aluminum and the blades are now paper cutters.

4.5.1 Result



Figure 4.16 – Third test result photos

The result is very good, the *cubicness* is achieved, but most of the results from X-cut are still connected by a very thin layer. The cycle time in average is 15 seconds. The cutting process was done four times, which in the last one; the clamp height is reduced by 2 mm. However, the result is still the same; most of the X-cut results are still interconnected.

The results for Y cut are all perfect.

4.5.2 Discussion

The X-cut result behaves as that may be caused by the varying sample thickness. The solution is to lower the clamp again or increase the clamping force by increasing the pressure going into the clamping cylinder.

Table 4.4 – Third Testing Summary

Result	Potential Root Cause	Action Plan
100% X Cut 100% Y Cut 0% X Complete Cut 90% Y Complete Cut The X Cut result still connected each other	Clamp not low enough	Clamp lowered Blades lowered

4.5.3 Revision

The clamp is lowered 6 mm, and the blade height is compensated using 6 mm acrylic (as a spacer between the blade holder set with the bed).

4.6 Fourth Test

The fourth test is conducted on 28 May. In this test, the researcher will look for the problem by adjusting many kinds of variables.

4.6.1 Result

Table 4.5 – Fourth Test Results

Trial	Condition	Result
1	Clamp is 2 mm lower than the previous test	The X-cut still interconnected.
2	X-cut is not used, the cut is made in Y-cut station, and then the noodles are manually rotated 90 degrees, and then do the Y-cut again	Perfect cubes, all are cut into cubes.
3	Normal cut, only the clamping pressure is increased to 4 bars, and the cylinder pressure is 5 bar	Not success, aluminum chips everywhere (meaning the clamp pushes too much)
4	Same condition with trial number 2, only the clamping pressure is reduced to 1 bar	Perfect cubes, all are cut into cubes.

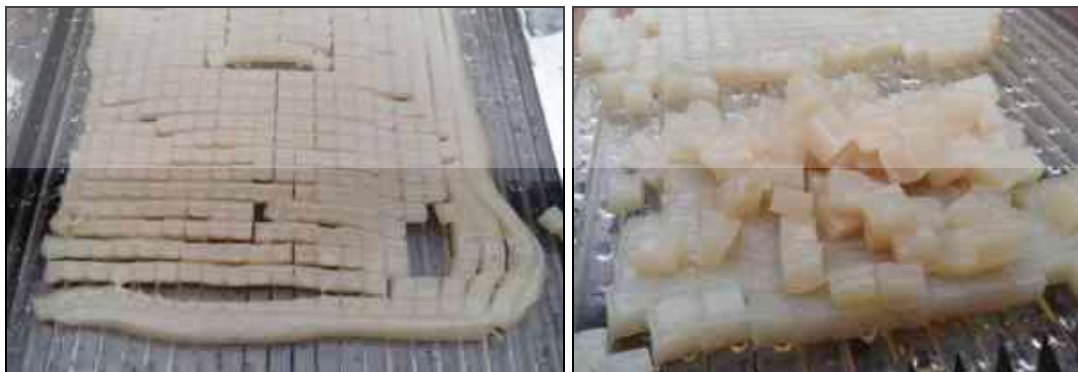


Figure 4.17 – Fourth test result photos

4.6.2 Discussion

This test shows that cutting with the method “cutter moves” has less issue than “*nata* moves”. Using only 1 bar pressure is enough already to do the cut perfectly. However, there may be variables missed by the researcher that makes the cut results differently.

For the next test, the angle of the X-cut blades is the one to be modified.

Table 4.6 – Fourth Testing Summary

Result	Potential Root Cause	Action Plan
90% X Cut 100% Y Cut 0% X Complete Cut 100% Y Complete Cut The X Cut result still connected each other	Cutting angle too low (15 degrees)	Add angle adjustor

4.6.3 Revision

To modify the angle of the blades without re-manufacture everything, only the mounting of the blades are going to be manufactured. The researcher made an adapter mounting.

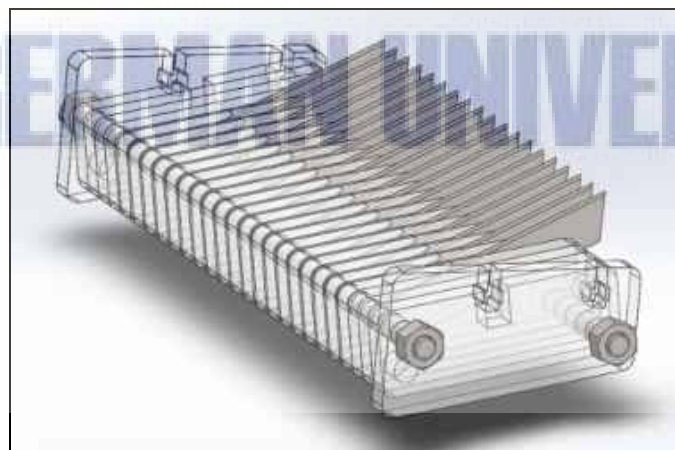


Figure 4.18 – Adjustable angle adapter mounting

4.7 Fifth Test

The fifth test is conducted on 11 June. In this test, the researcher will adjust many kinds of variables. In this testing, the researcher will also measure the cycle time for X cut process. Unfortunately, the *nata de coco* samples left are only six pieces.

4.7.1 Result

Table 4.7 – Fifth Test Results

Trial	Condition	Result
1	X cut is manually pulled by hand	The lower right part of the nata sheet = perfect cut. t = 21.36 s
2	Pressure is dropped by half, speed is also dropped by half	Y cut interconnected (0.1 mm layer) X-cut interconnected (1 mm layer) t = 37.52 s
3	X-cut blades are set at 20 degrees.	Y-cut and X-cut both perfect cuts, only the result is not cubic. t = 28.08 s
4	X-cut blades are set at 25 degrees.	The front part of the <i>nata</i> is cut perfectly, the rest is left behind by the clamp (stuck when going through X-cut blades) t = 37.52 s
5	Increase pressure and speed back to the beginning.	The rear right part of <i>nata</i> is left behind by the clamp, the rest is cut perfectly.
6	All the same with previous condition, only the rear part of the clamp is lowered by 1 mm	The one third rear right part of <i>nata</i> is left behind by the clamp, the rest is cut perfectly.



Figure 4.19 – Fifth test result photos

4.7.2 Discussion

The result of this testing is almost perfect, only the noodles are shifted when entering the Y cut area because it goes through a set of slits while being clamped. To smoothen the entering of the nata sheet into the Y cut area, a transfer plate has to be added. A transfer plate is an additional plate acting as a temporary flooring, which has the same height with the bed.

Table 4.8 – Fifth Testing Summary

Result	Potential Root Cause	Action Plan
95% X Cut 90% Y Cut 80% X Complete Cut 100% Y Complete Cut The result is 	The noodles shifted	Add transfer plate

4.7.3 Revision



Figure 4.20 – The implementation of transfer plate

A new transfer plate is used, placed on top of the Y cut area, and then removed after the nata enters the area perfectly.

4.8 Sixth Test

Before the sixth test, a new sample from *PT. Coco* has arrived. The sixth test then was conducted on 10 July 2017. Transfer plate is used. Not only when entering the Y cut area, it turns out the transfer plate is also useful for initiating the process. It can be used to cover the *nata* when the clamp is positioned above it in the initiation process. It has been quite a hindrance before since the *nata* often was stuck below the clamp, even when the clamp is in fully retracted position (because of the varying thickness). The new samples are also thicker than the sample before (10-12 mm, before were 6-8 mm).

4.8.1 Result



Figure 4.21 – Sixth test result photos

4.8.2 Discussion

The result for the sixth test is perfect with minor problems. For the cutting, it is perfect already. Both X cut and Y cut has perfectly cut all the way through the *nata* (no more connected pieces). However, some of the *nata* noodles ($\pm 30\%$) were tucked away in X cut area, because X area is lower than the bed by one millimeter. The area must be leveled off.

Table 4.9 – Sixth Testing Summary

Result	Potential Root Cause	Action Plan
70% X Cut 100% Y Cut 90% X Complete Cut 100% Y Complete Cut The result is stuck in X cut area	The X cut area not level	Level the X cut area Add scrape

4.8.3 Revision

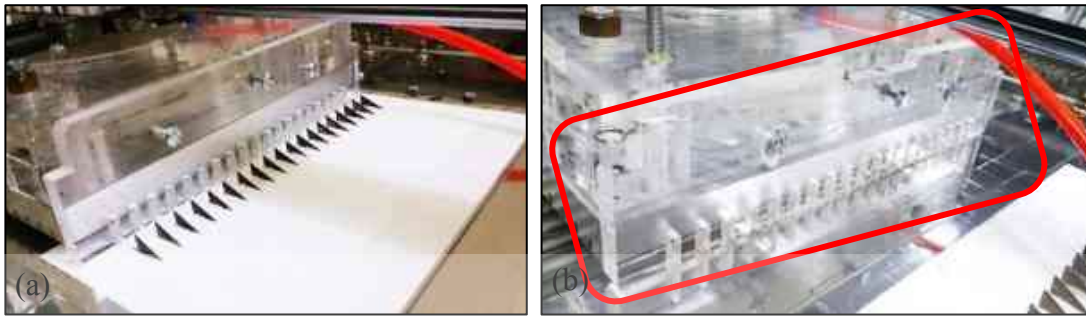


Figure 4.22 – The revision, (a) leveled X area and (b) scrape

For leveling the X area, vinyl stickers are used. Vinyl stickers are made out of plastic, exposure to water will not be a problem. The researcher cut off the stickers from A3 sheets into the intended dimension, cut 19 slits for the blades, and then layered it by 12 times to achieve the thickness of one millimeter. The last layer is made to cover the whole center module bed to smoothen the transition.

4.9 Seventh Test

The thesis defense is nearing, and the last yet determining test was conducted on 20 July 2017 as the seventh test. Up to this point, all electrical wiring has been functional already. All control of the actuators is done using the control panel. However, the Y cut sequence and transfer plate usage still are done manually.

4.9.1 Result



Figure 4.23 – Seventh test result photos

4.9.2 Discussion

Unfortunately, even after all variables have been dealt with, actuators with high pressure also has been implemented; the result has gotten way much worse. The X cut

works smoothly, with cycle time below 3 seconds (the X cut cylinder was supplied with six bars of pressurized air). However, the result was still connected each other, even worse than before, when it also was connected. To top it off, the Y cut, which usually has no issue, at that moment was having a big issue: it requires very big force, to the point it is very hard to be pulled by one hand. It must have something to do with the blades sharpness. It turns out; all of the blades have become dull. It has to be replaced.

Table 4.10 – Seventh Testing Summary

Result	Potential Root Cause	Action Plan
90% X Cut 80% Y Cut 5% X Complete Cut 100% Y Complete Cut Too much force necessary	All blades become dull	Change the blade (inapplicable for the time being) Change blades positioning

4.9.3 Revision

Other than replacing all the blades with the new one, the researcher has come up with a fresh idea for the blades positioning, which might be a solution to ensure the X cut to cut completely (no more connecting with each other).

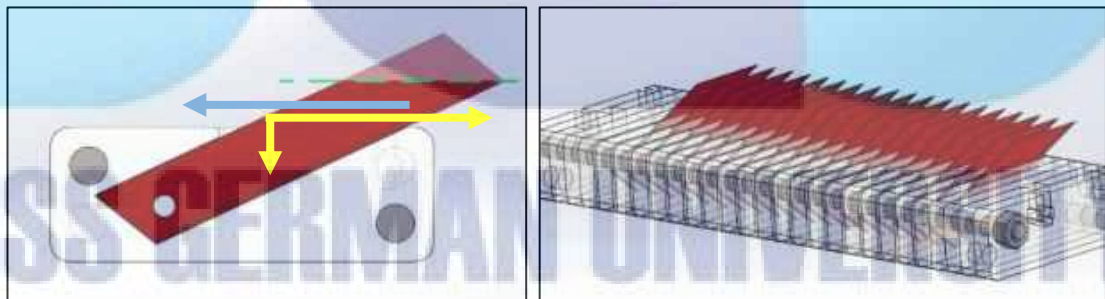


Figure 4.24 – Revised blade position (a) side view and (b) fully assembled view

In the new design, the blades are positioned upside down, with the cutting edge facing downwards. To compensate for the cutting angle, the blades need to be ground parallel to the holder, (shown as green dash line in Figure 4.24a above) The *nata* is headed in the blue arrow direction (depicted in Figure 4.24a above). It is expected that using this design, the *nata* will clamp itself when cutting since the force acting when cutting will be in the direction opposite of blue arrow and downwards (shown as a yellow arrow in Figure 4.24a above). The complete cut should be easy to achieve in this configuration.