DELIVERABLE 3 : JUMPER CUTTING/STRIPPING MACHINE

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Group N°12

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1. Context of the study

Our project consists in making a jumper cutting and stripping machine, ordered by Frédéric Mantegazza. This machine should be used in schools (above all Ense3) for learning and research purposes. Its main functions will be to cut and strip wires in order to manufacture jumpers for electrical devices such as breadboards.

Our group decided to carry out this project using a kind of AGILE method. This seemed ideal to us because our client is not a professional and his needs can change over time. Moreover, our project is practical because it can be separated into four sub-projects which can fit with the cycles of the AGILE method. Inside each cycle, we can focus on 2 sub-systems, which is easier for us to organize and it provides an efficient way to work. We are currently in the second AGILE cycle:

Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
preparatory phase		First Agile cycle			Second Agile cycle		System assembly and delivery	

Since deliverable 2, we have been able to improve some of the functionality of the jumper machine and create new ones. In particular, we finished the wire guiding part with the extruder and the cutting part. The new functionalities are the stripping of the wire outer sheath and the bending.

As during the first AGILE cycle, we formed 2 groups of work in order to be efficient :

Floriant - Virgile	Bending system
Clara - Bastien - Benoît	Stripping system

The objective of this deliverable will be to present to you the progress we have made during the last 2 years and the reasoning that led us to design the system in this way.

2. Project tasks advancement and achieved work plan : Current developments

The system must transform AWG 23 reel wire into jumpers which are bent wires with stripped ends. For this, we complete the process imagined in the first AGILE cycle as follows:

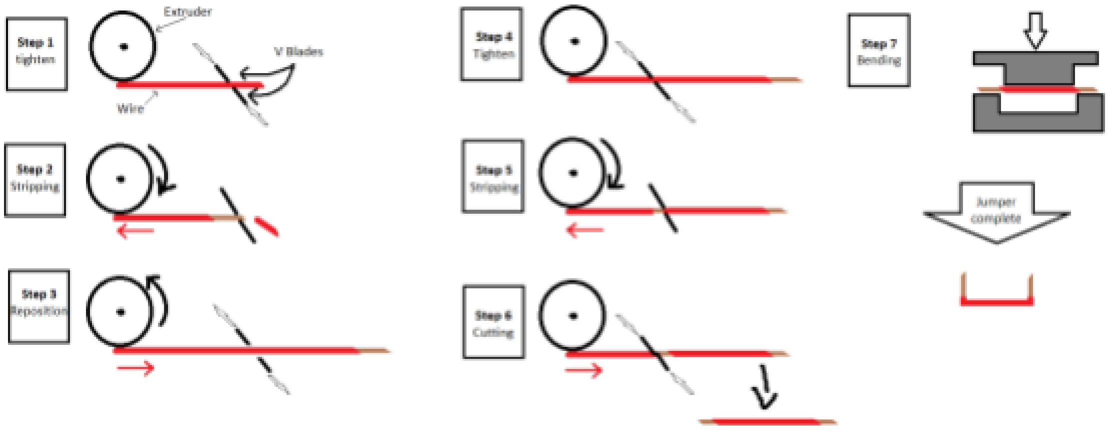


Figure n°1: program steps

This flow chart has been updated with the addition of the oblique cuts and the folding part. It seems unlikely that we will change the different manufacturing steps in the future, at least for this year.

As said before, two functionalities have been developed : the stripping and the bending.

For the stripping system, its purpose is to cut the sheath with V blades without significantly damaging the wire core. Then move the wire to slide the sheath over it. For this feature, we have the opportunity to reuse the existing cutting and dispensing system. This saves us development time, money and reduces the complexity of the system. In addition, the 45° sheath cut was not a problem in the implementation. The difficulty lies in the fact that we have to adapt the arduino code to obtain a precise movement of the blades during operation.

We now have a straight wire of a certain length and it is stripped at both ends. It must be bent to obtain an agreeable jumper. Given the time we have left and the complexity of such a system, we decide to focus on the manual operation of the bending. An automation will be planned, but only when we are satisfied with the implementation of our 3 previous subsystems.

We are now going to present you various points on which we worked to reach our objectives.

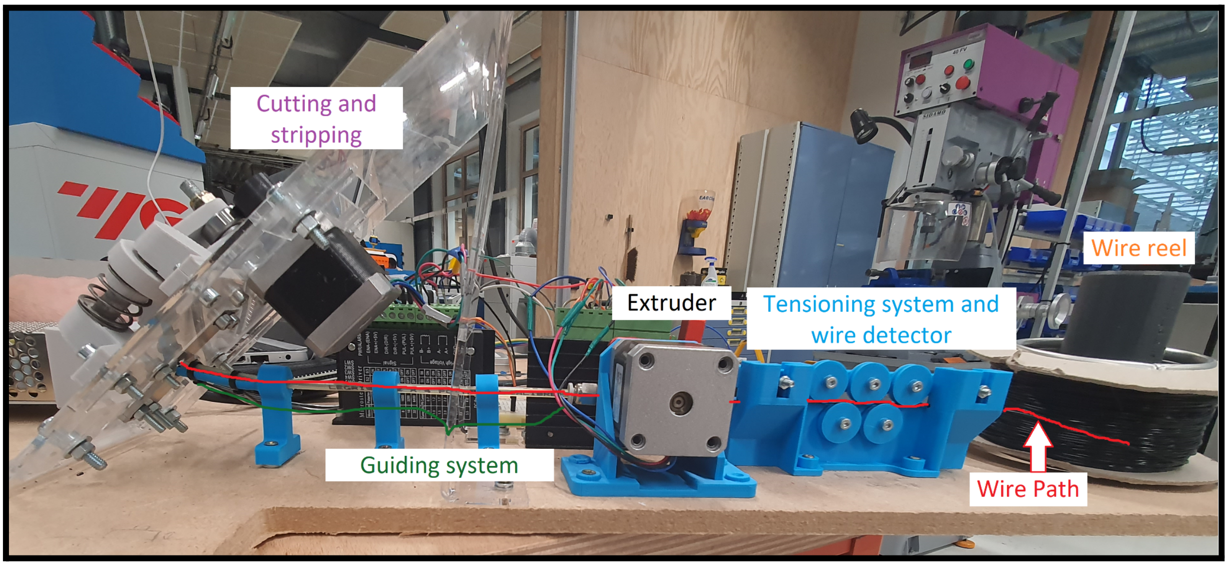


Figure n°2 : Current state of the Jumper Machine

- WIRE GUIDING

Problem : The wire was well guided by the extruder, but because of gravity, the wire fell back and therefore did not arrive between the blades. The angle was wrong. We tried to guide it with cylindrical supports [], but the wire kept deviating from its trajectory, making it impossible to cut.

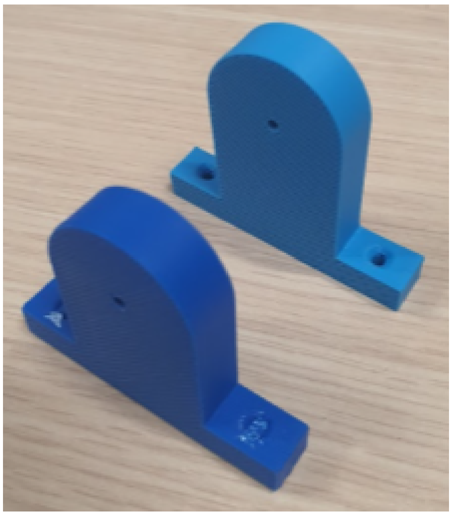


Figure n°3: Original wire guides

Solution : We printed thinner guides and used a tube to guide the wire. The first tube, made of silicone, was too soft, and we had the same guiding problem as before. So we switched to a more rigid PTFE tube.

Result : The wire is much better guided and stays in place. However, we have had problems with the height of the wire in relation to the blades. For this, we put washers under the guide closest to the blades to raise it in height (this is obviously a temporary solution). We also had to put clamps to keep the PTFE tube in place [].

Alternative solutions that could have worked : We also thought of putting talcum powder on the wire to improve the guidance. However, as the guiding is finally done without any problem, we discarded this solution.

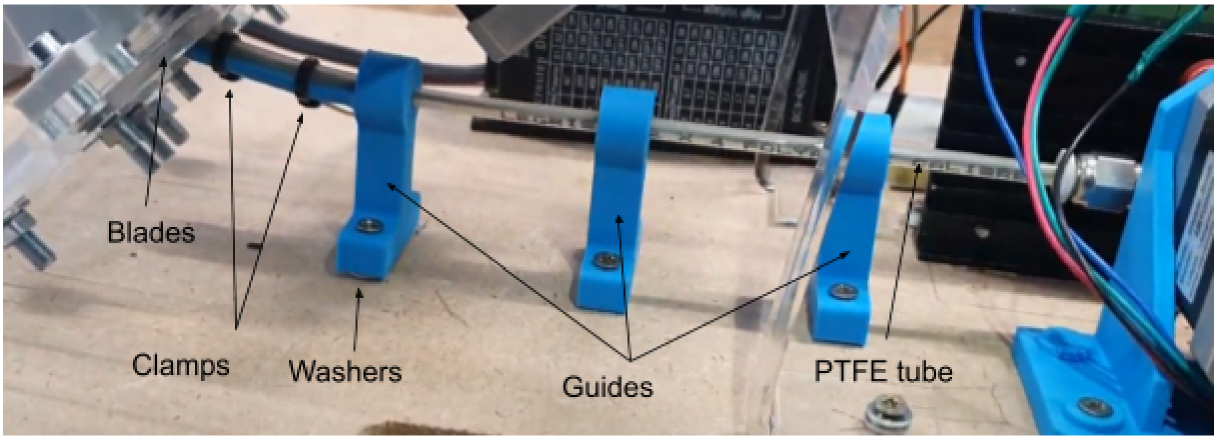


Figure n°4: Latest guiding system

• Cutting part

Problem : The major problem we had was that the motor would skip steps when cutting. This was due to the fact that the cam had too large a radius (31.1mm) which increased the lever arm. Also, without the guiding of the wire, the blades were pushing down the wire, making it more difficult to cut.

Solution : We re-printed the cam in 3D with a smaller radius (18mm). We also thought of potentially shortening the slide springs by cutting them in order to reduce the forces at the end of the cam's stroke. However since the reduction of the cam's radius was successful, we didn't shorten the springs. The guiding of the wire also allowed it to present the wire with a slight angle up, then cutting around 45°.

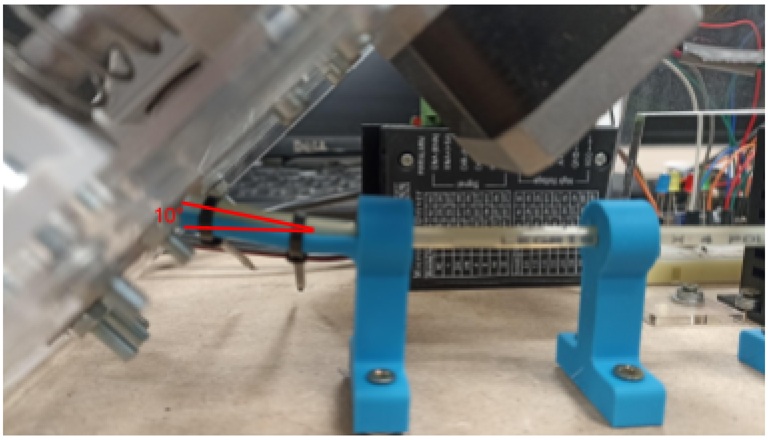


Figure n°5: Wire guiding with an angle

Result : The motor does not skip steps anymore. The cutting is smooth and effective.

Alternative solutions that could have worked : Another solution to the limit of the motor torque would have been to lengthen the slides to reduce the torque to be provided by the motor.

- WIRING + ARDUINO CODE

Problem : The drivers we had were very limited on the current they could deliver, they were also heating up very fast. Also, the old wiring wasn't very safe, there were a lot of soft wires, easy to tear out of their slots, and aparrents charged parts. Finally, the old power supply wasn't powerful enough to power two stepper motors

Solution : We changed the drivers because they burned out very quickly due to a too strong current. The new drivers now have a safety feature.

We used the first jumpers we made to prototype the connections on the breadboard and keep the minimum amount of soft wires. Most of the other components were also shortened to be flush with the breadboard.

We also soldered the cables of the switch and a new power supply, more powerful and sufficient for our use, that we enclosed in 3D printed parts for protection.

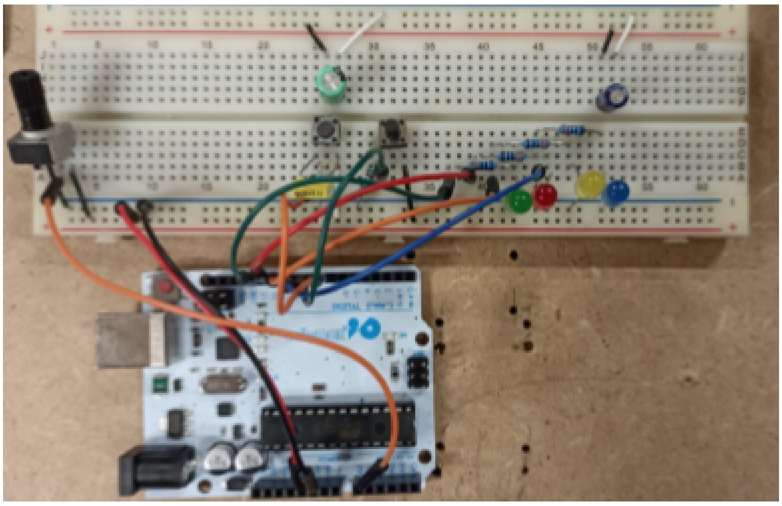


Figure n°6: New wiring

Result : Now the wiring is cleaner and easier to re-do when we have to assemble the machine. Also, even with long tests, we haven't felt the drivers warming up yet and we're confident to push the machine for longer tests in the next phase. Finally, the wiring is much more secure, limiting the risk of breaking the system and most importantly the risk of an electric shock.

• Cut and stripping stress

In the need to provide a dimensioning of the stepper motors and allow us to justify our experimental choices. We have performed experiments on the forces related to stripping and cutting.

Our customer asks for a cutting angle of 45° to allow a better insertion of the jumpers in the breadboard. Nevertheless, we would like to see how the cutting force evolves as a function of the insertion angle. For this purpose we have realized the following experimental device:

Figure n°7 : dispositif expérimental

It allows us to measure with a dynamometer the force in Newton applied to the wire at the moment of cutting. The insertion angle is adjusted by hand with a protractor and the wire is guided in a tube. For each value of angle, 5 measurements of force are made and averaged.

We obtain the following results:

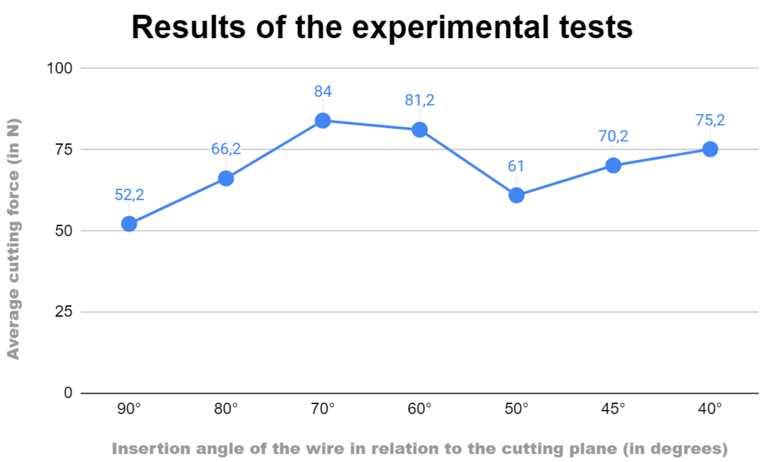


Figure n°8 : Courbe des résultats

We observe that the lowest value is 52,2 N corresponding to an angle of 90°, however this goes against the requirements which impose a bizot cut. So the most interesting value is 61 N corresponding to an angle of 50°. This verifies our observations made with the guide system which reduces the 45° angle by about 10°. We still need to discuss with the customer whether the cutting angle can be reduced.

For the stripping, we observed with a dynamometer that 4 cm sheath is stripped with a force of about 1 Newton. However, this depends on whether the sheath has been pre-cut. In case of bad stripping, the stepper motor can pull with the extruder up to 17N, but this is not enough. It is therefore assumed that the sheath will always be cut properly.

• Stripping setting

Problem : We always knew precision would be the major problem for stripping the wire, we need to set the blade close enough to cut the sheath and the blade position might change while the power is out (someone moving or the cam aligns to the wrong step during powering creating a small offset).

Solution : We added a small potentiometer to one of the analog pins of the arduino and one button to switch to a "setting mode" for stripping. The user then lets a small portion of the wire exceed and can use the potentiometer to move the cam to set the blade as close to the core of the wire. One push of the new button and we exit the mode and set the position for the stepper motor.

Result : We are getting consistent results when the blade is correctly set even though the major issue is that there is no objective way to assure the blade is correctly set before launching the program, especially for a new user who might take a while to figure it out.

Adding some kind of gauge to set the blade could help, but the user would have to be careful not to bite in the material with the blade if it's too soft or skip steps, then completely change the position of the stepper in the arduino code, if it's too hard.

• Wire stripping

Problem : During manual testing, we realized that the core of the wire tends to be stuck in the blade because we need them really close together to cut enough sheath of the wire.

Solution : We turn the cam to cut the sheath of the wire (close to the wire's core), then we turn the cam back by a small amount of steps, just enough to create more space for the wire, but still retaining the sheath when stripping the wire.

Result : We are able to strip wires. However, it happens that some wires are not stripped because the blades do not bite into the sheath. After several tests we have come to the conclusion that this happens for one jumper out of 10. It also happens that some jumpers have their edges slightly bent. This is probably due to the initial shape of the wire in the wire spool. The wires are all the same size with a tolerance of ... %.

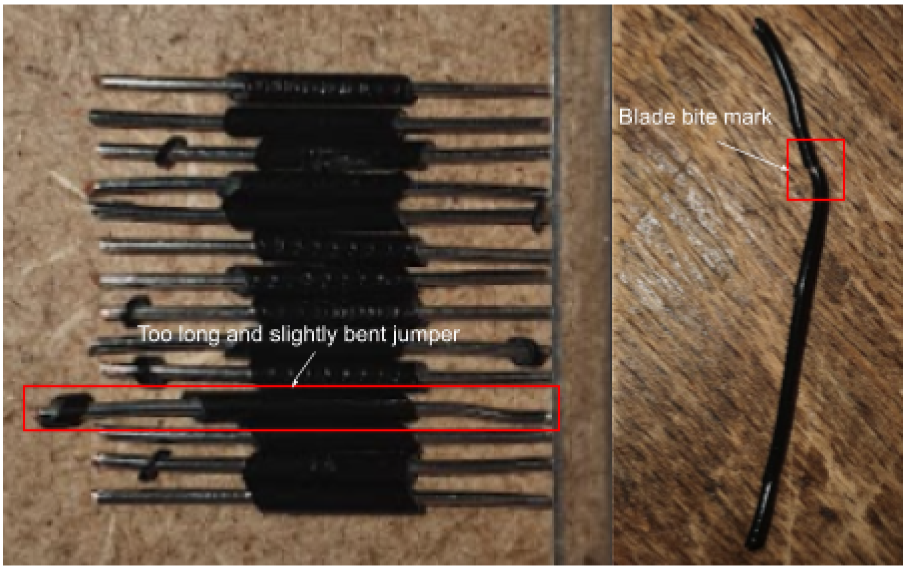


Figure n°9: A set of 10 jumpers (left) and a non-striped jumper (right)

Problem: It is necessary to find the process for bending the jumpers. In particular, we need to make it easier and faster for the user.

Solution: For the bending of the wires we chose to make matrices with the 3D printer. Indeed, 3D printing is cheap and each Favlab has a 3D printer. So in case of loss or breakage, users will only have to recover the CAD documents on GitHub.

Initially, there were four sub-functions for the function “bending the wire” and we have added two more in the requirements (c.f. Appendix 1):

- 4.5: “do not dealign the edges”
- 4.6: “do not distort the edges”

We had to make these matrices several times because the bending angle was not good. Finally, our matrix (c.f. figure n°10) is composed of three smaller matrices (top, middle and bottom), a spring to exert pressure on the jumper, a tab to facilitate the extraction of the matrix and a "buzzer" to simplify the application of force on the die by the user. The top and middle matrices have a scale form. Each step corresponds to a specific jumper length.

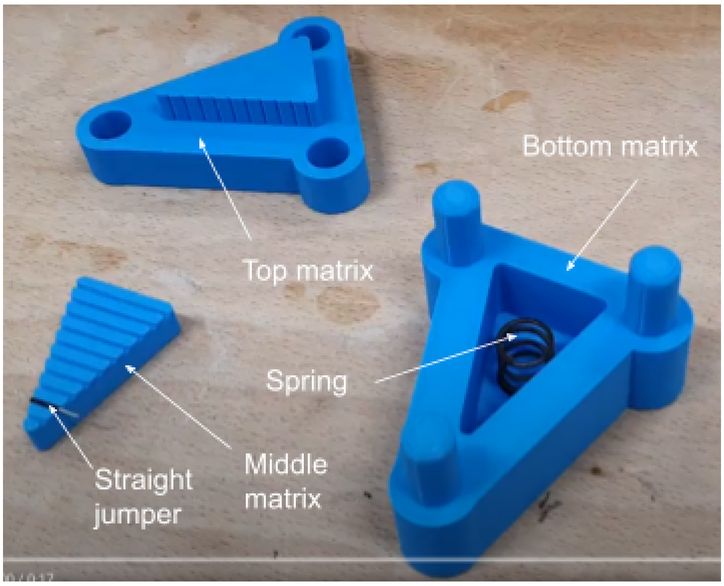


Figure n°10: Latest bending matrix (buzzer and tab not represented)

Before achieving this result, we started by creating a simple middle die that allowed us to manually bend jumpers to any standardized size. We quickly realized that this would cause a misalignment of the jumper's edges, but more importantly, that the upper part of the jumper tends to lift up during bending.

The solution to this problem was to design a part that blocks the top of the jumper. However, our goal is to automate the bending of the jumpers. For the moment, we are at the stage of bending that can be considered as "semi-manual". Indeed, the user just has to place straight jumpers in the middle die, and then position it at the level of the lower die in which there is a spring that allows the middle die with the bent jumpers to come out. To prevent the upper part of the jumpers from lifting up during bending, it is enough to position the third and last die which is guided by stubs (3D printed with the lower die). Finally, it only remains to press the upper die in order to realize the bending of jumpers.

It is sometimes difficult to pull out the middle die from the lower die, so we have improved its design by adding a tab that makes it easier to remove. The last improvement is based on a mushroom-shaped part that allows the user to easily press the upper die using only one hand.

The latest evolution in the design of the bending module is related to the grooves in both the upper and lower dies. Not knowing the impact these grooves would have on the bending of the jumpers, we tested several combinations to find the one(s) that offer both the best bending angle and alignment of the jumpers edges once bent.

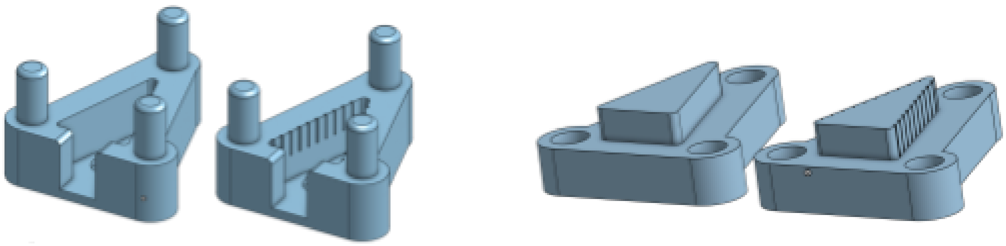
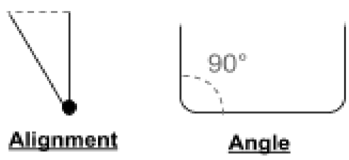


Figure n°11: Dies with and without grooves



Lower Die / Upper Die	With Grooves	Without Grooves
With Grooves	Alignment : Yes Angle : No	Alignment : Yes Angle : Not Bad
Without Grooves	Alignment : Ok/Not Bad Angle : No	Alignment : Yes Angle : Yes

Table 1: Study of the impact of grooves in the lower and upper dies

From the table above, it appears that the best option is to have no grooves in either the upper or lower dies. Because the jumpers were not too bad when using the lower die with grooves and the upper without, we would like to do more tests to definitely find the best design.

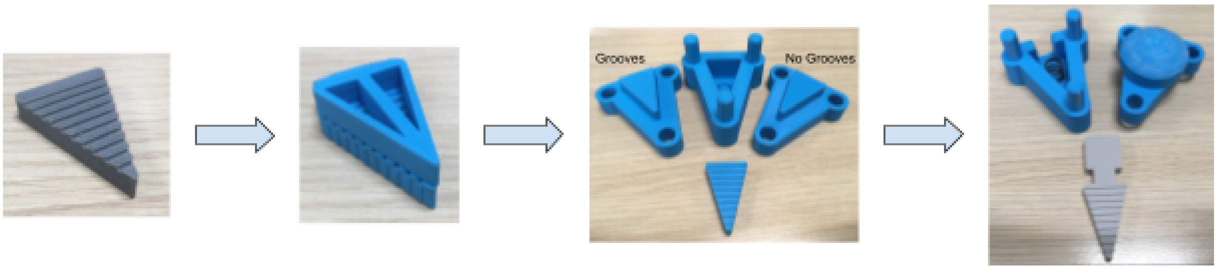


Figure n°12: Evolution of the bending module

Result: We can easily bend the wires. However, the jumpers do not fit well in the breadboard. We think this is due to the fact that we did not take into account the 45° bend length. Indeed, in the CAD we put on the matrix the exact width we wanted for the jumpers, without taking into account this offset. Furthermore, there is an elastic return that doesn't enable us to get the ideal angle of the edges that we are looking for.

Next step: Having one lower and one upper die, and a set of ten middle dies of different sizes with their adapters for each jumper length.

3. Risk analysis

Nothing has changed much since the last phase.

With the progress we have made on the prototype, we lowered the impact of this part.

Also, we haven't encountered any kind of big problems with the server hack: we just switch entirely on Google Drive and save all of our data weekly on an USB key.

Now the main risk we identify for the project, now and in the future, is the order and shipping of parts, especially receiving them on time. The main objectives will be to decide what we really need and order it to the $Ense^3$ Fablab quickly for the next phase.

4. Project costs estimation

We have worked, since the beginning of the first AGILE cycle, a total of 19 weeks. We consider that each member worked about 5 hours per week (low average). Knowing that we are students and that we don't have the experience of a seasoned engineer, we consider that we are paid 28€/h.

This makes our labor cost of **13 300,00 €**

We made 15€ more process compared to the first cycle. This makes us now a total of **51,33 €.**

Plus the Bill Of Materials where there were some components upgraded with a total of **223,63€.**

Our project current cost is **13 574,96 €**

Total cost

Labor Cost	13 300,00 €
Process Cost	51,33 €
B.O.M.	223,63 €
	13 574,96 €

Note that by adding the "process cost" and the B.O.M. (which is worth **274,96€**), we are still below the price set by the customer of a maximum cost of 300 €.

5. Work Plan - objectives, Key elements, difficulties …

Our goal at the end of this cycle was to be able to build functional jumpers. However, we inherited some problems from the first AGILE cycle that we had to solve. These recurring difficulties are now solved:

- The NEMA 17 stepper motor in the cutting system was skipping steps. This was causing the cut to go out of adjustment and the wire was not being cut or stripped properly. We deduced that this was due to a lack of torque. Either we installed a gearbox (cumbersome and requiring more precision on the control), or we changed the size of the cam. We reduced the size of the cam to increase the torque. It worked.
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- When stripping, we had a problem because the roller of the extruder tended to eat the wire sheath if it was blocked during stripping. This problem was solved by perfecting the trajectory of the blades as explained in the "Wire Stripping" section.

- The NEMA stepper motor drivers were a big problem for us, as we were using Pololu DRV8825. They have the disadvantage to be noisy, to be fragile, to go out of order easily during the manipulations and to heat a lot. That's why we replaced them with TB6600 which are more expensive but more reliable in their global functioning.

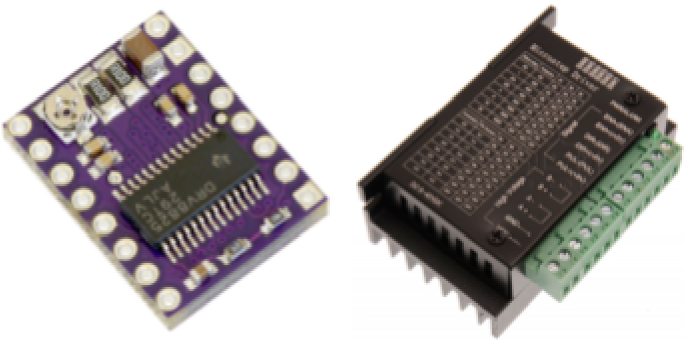

Figure n°13 : Driver DRV8825 and TB6600

With the resolution of these issues and our recent progress, our goal has been achieved! As shown in figure n°9, we performed manufacturing tests on a 15 jumpers of 5 pins length. And this last one concluded positively. The functional principle of the machine is thus validated and the customer is satisfied.

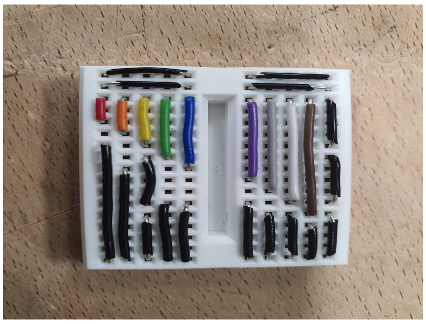

Figure n°14 : breadboard with our jumpers (in black)

6. WHAT'S NEXT?

Now that the system is up and running, we still have 2 months to correct details to ensure that next year's takeover group is in the best possible condition.
This to-do list appears in the last cycle of our Gantt named "System assembly and Delivery".

- Try to find other solutions in order to get a better bending quality, especially by taking into account the elastic return that we are not able to offset with the current system. We also are going to make a matrix by jumpers length in order to be able to make several jumpers of the same length at the same time.
- The process should be tested for small jumpers of 3 or 4 pins in length.
- Make an User Interface more comfortable than currently (modify the code on the computer directly). We planned to use a joystick and an LCD with I2C protocol to spare pins on the arduino UNO.
- Find a method which will facilitate the wire installation inside the system.
- Implement a part that will help us to grapes the sheat and the jumper after the stripping operation.
- Currently, we have an interrupt link to the power supply. However, that's not an emergency shut down. So we want to add an emergency stop push button.
- Change the support board of the machine.
- Make cable management and improve the wire connections pins to make the system cleaner and more reliable.
- We are also gonna order the materials to give back what's owned by GInova.

Due to the amount of work done by the group and the progress made in the last week, we plan to meet with the client during the week of April 4th. This will allow us to adapt our route plan according to his feedback.

Appendix

G12 - Jumper machine - Requirements - V3.1

Functions	Id	Version	Sub-functions	Criteria	Description	Level	Tolerance	Control method
Stripping	3.1	V1.2	Remove the sleeve from the wires' edges	Visual	There is no more sleeve on the area to be stripped			Visual
	3.2	V1.2	Have the right size of edge	Length	The stripped edges must have a given length	6.5 mm	-+0.5mm	To be defined with the metrology course
	3.3	V1.2	Do not damage the conductor	Quality	Check that there are no marks on the conductor in the stripped area			Microscope
	3.4	V1.2	Control the waste	Practical	The 2 sleeves must be taken by the system and not become harmful elements for the good functioning of the rest of the process			Visual
Bend the wire	4.1	V1.2	Bend the edges at the right angle	Angular	The 2 edges must be bent at the right angle	90°	-+5°	Taking of pictures to allow a visual verification on software
	4.2	V1.2	Do not distort the body	Straightness	After the operation, the straightness of the body must not have shifted from the initial axis of the wire	0.5 mm		Taking of pictures to allow a visual verification on software
	4.3	V1.2	Do not damage the jumpers	Quality	There should be no visible damage to the jumper after the edges are bent			Visual
	4.4	V1.3	Respect the radius of curvature	Bending	The bending must not influence the geometry of the jumper	<= 1 mm		Visual
	4.5	V3.1	Do not dealign the edges	Alignment	The edges must be aligned when looking at the profile of the jumper	0°		Visual
	4.6	V3.1	Do not distort the body	Straightness	After the operation, the straightness of the edges must be kept			Visual

Bibliography