Final report

Open Source Plastic Recycling Machine

Date : 17/05/2022

Groupe N° : 14

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------------------- SUMMARY -------------------

Part 1 - PROJECT SUMMARY

Part 2 - PROJECT MANAGEMENT PART

Part 1 - PROJECT SUMMARY

A/ Context of the study - Main objective of the project

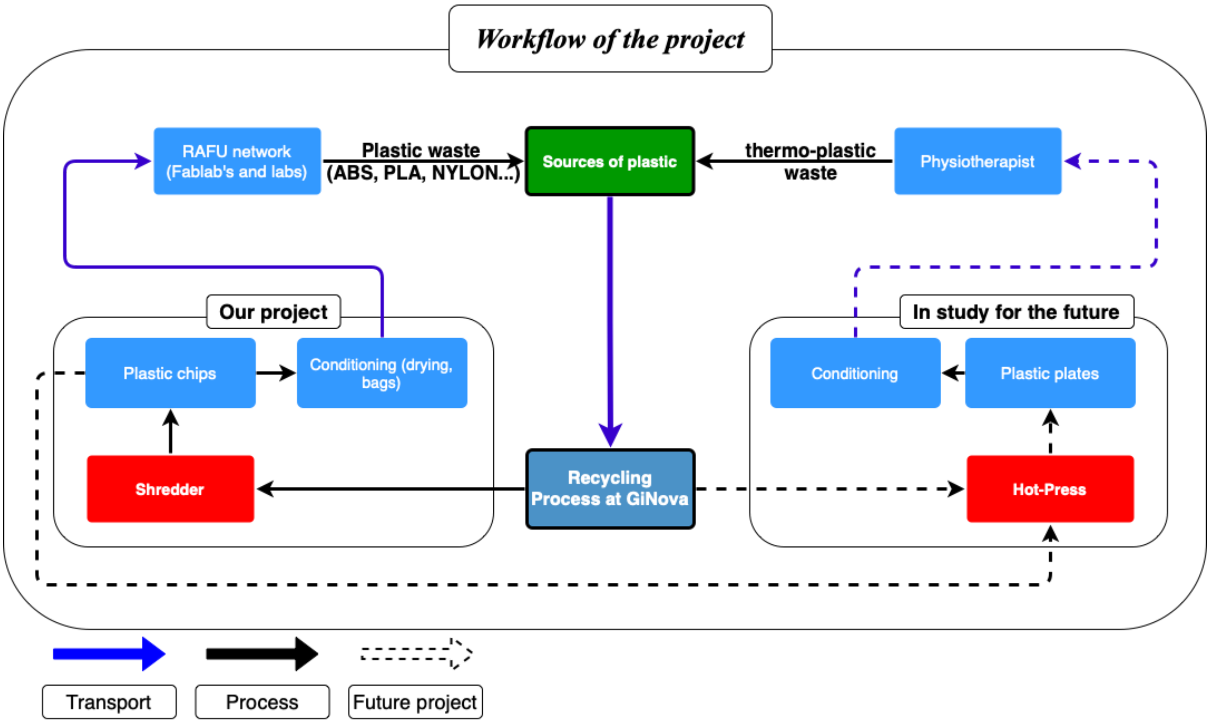


Figure 1 : Context of the project

The objective of our project can be summarized by finding an open source solution to recycle different kinds of plastic waste. In our more specific situation the objective is to first provide a plastic recycling solution to the **RAFU network**. This network gathers the **labs** and **Fablab of the UGA.** The research and the craft made there, create plastic waste especially with the 3D printing process. It would be a huge improvement if it became possible to recycle these plastics. In the future this solution could be extended to other kinds of actors who use plastics such as **physiotherapists** who make splints with thermoplastic or industrial materials (such as **Chabloz company** with nylon waste).

The objective of the group was to find a way to make the creation of 3D printing filament easier with the professional recycling machine available in the **fabMSTIC**. The main point of improvement is to work on the size of the pieces of plastic that had to be recycled. Another important phase is to organize the collection and the travel between the different recycling spots and users. Another point that could be developed is the creation of plastic plates to give a new life to the plastic collected.

To work on this project, the group was given a prototype of a plastic shredder and a hot-press. These two prototypes were not fully finished and need to be improved in a matter of capacity and mostly about safety to be used properly.

Since the first deliverable the work was focused between a fine study of the way to recycle plastic, the design of the prototypes improvement, and the creation of the Open source documentation on a Github repository.

B/ Specifications

At the beginning of the project, we took the time to meet the client at fabMSTIC to understand his different expectations about the project. A few weeks later, after doing some research on our side, we went back to him with a first draft of the specifications. During this meeting, we were able to discuss it with him and converge on our final specifications that we have been using ever since.

ID requirement	Name
FR1	The shredder needs to work on a standard 220V 50Hz EU plug.
FR2	The shredder needs to respect the 1m50x1mx1m50 maximum volume to avoid cluttering the space.
FR3	The shredder needs to shred plastic into chips with a surface inferior to 150 mm² with a tolerance of 5%.
FR4	The shredder needs to stop in case of emergency in less than 3 seconds.
FR5	The shredder must be secured to prevent injury on contact (against moving parts and projectiles).
FR6	The shredder needs to have a power-on and/or operation indication that the operator can see
FR7	The shredder must not exceed the maximum accepted noise level.
FR8	The shredder should not transform one of the labs and fablabs of the RAFU network into a storage place for all the plastic chips.
FR9	The shredder needs to have a reverse function in case of blocking or any other mechanical problem.
FR10	The shredder and its installation should be stable and strong.
FR11	The shredder need to be able to shred 3D printed plastic part with a 50x50x50 mm dimension and 30 % infill

Figure 2 : Table of the requirements

C/ Presentation of the product and its suitability for the need expressed

This part will present the different improvements with a point of view of the requirement. For each requirement we will see how we answer the need and how we have verified that the requirement is respected.

- **FR1 and FR9** "The shredder needs to work on a standard 220V 50Hz EU plug." & The shredder needs to work on a standard 220V 50Hz EU plug.

To make the shredder work on a standard plug we have chosen to use a converter to connect the 3 phase engine to the 1 phase network. This solution presents lots of advantages like the possibility to command the speed and the direction of the rotation or to create an emergency stop scenario.

We can now connect the system to a standard plug, the requirements are now verified.

Figure 3 : Converter

- **FR2 :** "The shredder needs to respect the 1m50x1mx1m50 maximum volume to avoid cluttering the space."

The actual size of the device is 750x60x1400 mm. This limitation does not have an impact on the design we made. We can say that this requirement is verified.

- **FR3 :** "The shredder needs to shred plastic into chips with a surface inferior to 150 mm² with a tolerance of 5%."

To satisfy this requirement. The team had chosen to make a grid under the shredder. This grid was made in steel cut at the ense3 Fablab. This grid had 2 functions, first, it can sort the pieces of plastic too big for the exigence. Moreover the grid permits the knifes to grab these big pieces and shred them again until they reach the size desired.

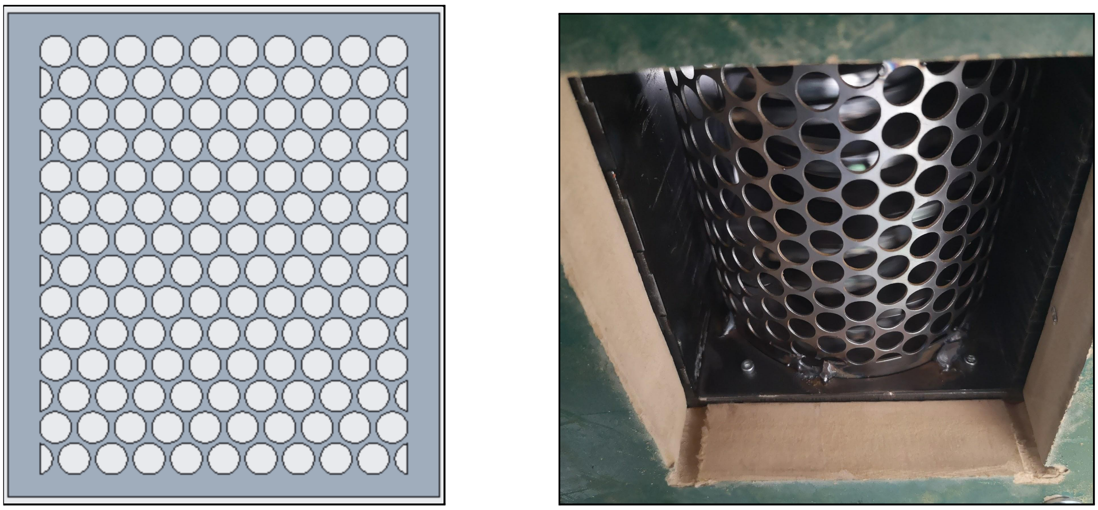


Figure 4 : CAD and realization of the grid

The actual grid was designed with circular holes. We decided to measure the performance of this grid with an experimentation on 100 chips taken from a session of shredding.

To proceed we made an hypothesis on the shape of the chips and assimilated them as rectangles. This approximation looks realistic with the global shapes of the chips we had.

Figure 5 : Chips obtained after shredding

The results were very satisfying because the average surface of the ships turns around **122 mm²**. We can easily say that this requirement is Verified.

- **FR4** "The shredder needs to stop in case of emergency in less than 3 seconds."

In order to proceed on an emergency stop and to fit with the security norm, we put an emergency stop button on the system. When the button is actionned it will directly cut the electrical power of the shredder.

Figure 6 : Emergency stop button

To ensure that this criteria is respected we timed the stop of the blades when the emergency stop button is pushed. We measure around **2s** to stop the blades, the requirement is verified.

- **FR5** "The shredder must be secured to prevent injury on contact (against moving parts and projectiles)."

To protect users from injuries we made a hopper that blocked the access to the blades and we made the access more difficult with metal panels inside. It's planned to design and add a cover for the rotating parts but is not present yet because we are waiting for the new engine to make sure we have the good measure. When we write these lines we can only say that the requirement is partially verified but it will soon be completely verified.

Figure 7 : The shredder and it's hopper

Moreover a security rules document was made and displayed on the device to inform users on the good way to use it.

- **FR6** "The shredder needs to have a power-on and/or operation indication that the operator can see"

To show clearly if the system is working or not we placed a Flashing light that turns on when the system is working. This system is put at the top of a metallic bar in order to have a high visibility on the status of the shredder to everyone around.

Figure 8 : Flashing light

- **FR7** "The shredder must not exceed the maximum accepted noise level."

The technology used in this project is relatively quiet because it is composed of an electric motor and the rotation is guided by bearings. Moreover the shredding noise is pretty acceptable compared to other devices that can be found in the lab. At 1 m from the shredder we can measure a sound intensity around **60 dB**. It represents the sound level of a normal conversation and it is far from the danger zone, which is above 80 dB, so the requirement is verified.

- **FR8** "The shredder should not transform one of the labs and fablabs of the RAFU network into a storage place for all the plastic chips."

To prevent the place where the shredder is installed to be a sort of plastic waste room, each plastic that came for being shred is put in a bag and labeled to make sure it came with a recycling purpose and, have a place to send it once the operation is made. With this procedure all the material has a destination and is not let down around the shredder. Thus this criteria is verified.

- **FR10** "The shredder and its installation should be stable and strong."

We have chosen for the structural part of the installation to keep the table given by the GI-NOVA team that had a strong steel structure and most of all a hard wooden top. to make sure that all the effort can be supported by the wood,we made a FEM simulation that is explained in the next part. With the results, we can say that the plate will widely support the torque transmission. Considering all the previous information we can say that this requirement is Verified.

- **FR11** "The shredder need to be able to shred 3D printed plastic part with a 50x50x50 mm dimension and 30 % infill"

For this requirement, we can not say if it's verified or not because like for the FR5, we are waiting for the new engine that should provide enough torque to verify this requirement. Actually with the little motor we use it's possible to shred little plastic rafts but the motor stops frequently due to the power required.

ID requirement	Name	Verification
FR1	The shredder needs to work on a standard 220V 50Hz EU plug.	Verified: use of a converter
FR2	The shredder needs to respect the 1m50x1mx1m50 maximum volume to avoid cluttering the space.	Verified
FR3	The shredder needs to shred plastic into chips with a surface inferior to 150 mm² with a tolerance of 5%.	Verified: Study on the shredded plastic
FR4	The shredder needs to stop in case of emergency in less than 3 seconds.	Verified: Measured
FR5	The shredder must be secured to prevent injury on contact (against moving parts and projectiles).	In progress: a hopper and a cover have been installed. Lack a protective cover for rotating parts and the installation of an end-stop button to switch off the engine if the cover is opened
FR6	The shredder needs to have a power-on and/or operation indication that the operator can see	Verified: Flashing light
FR7	The shredder must not exceed the maximum accepted noise level.	Verified: Measured
FR8	The shredder should not transform one of the labs and fablabs of the RAFU network into a storage place for all the plastic chips.	Verified: use of labels to track each bag of chips
FR9	The shredder needs to have a reverse function in case of blocking or any other mechanical problem.	Verified: thanks to the converter
FR10	The shredder and its installation should be stable and strong.	Verified: through structural calculations
FR11	The shredder need to be able to shred 3D printed plastic part with a 50x50x50 mm dimension and 30 % infill	Not verified: requires a test phase when the shredder will be operational

Figure 9 : Monitoring of the requirements

D/ Presentation of technical and scientific work

At the beginning, we had in mind to maximally use the equipment that was given to us, including a 60 N.m geared motor. In order to reuse as much material as possible, we wanted to assemble this motor with our shredder for testing purposes. We obtained the following assembly (***Figure 10***) :

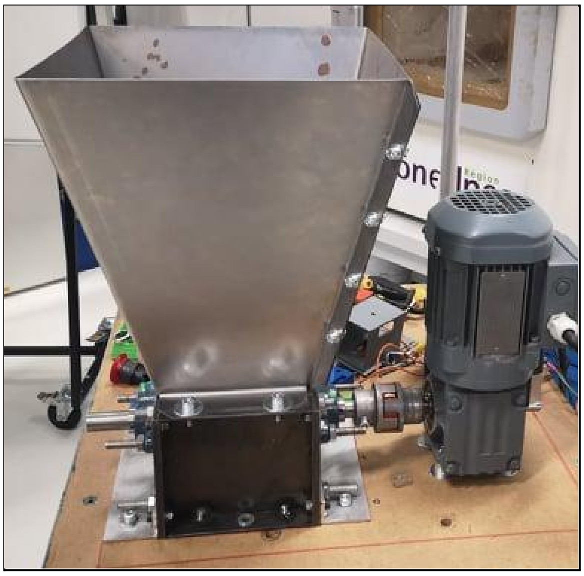


Figure 10 : First assembly of the shredder

This assembly only made it possible to grind very small pieces of plastic, so we realized that this geared motor would not be suitable: it develops too little torque to effectively overcome the force of the blades on the plastic pieces. It may seem that at this stage we have wasted a lot of time for nothing in trying to implement this solution but in reality it has taught us by experience some essential things for future choices such as: the choice of a coupling solution, the electrical connections of the motor and the three-phase converter, the assembly/ disassembly and the adjustment of the shredder blades.

For the future, we decided to keep only the structure of our shredder and the trolley in order to carry out further dimensioning tests to choose the ideal transmission (we did not want to buy material without knowing if it will be suitable or not). At this stage we knew that the solution will need a larger motor and gearbox, so the trolley will also have to be modified in the future to be suitable for this kind of material.

Experimental determination of the minimum motor torque required for grinding:

During the first semester, we were able to set up the shredder without its motor as explained before ***(Figure 11)*** on a test table. Using a one-meter solid steel bar, we made an experimental tool to determine the minimum torque needed to start shredding ABS pieces previously stuck in the blades. As shown in **Figure 12**, we placed weights at the end of the steel bar until the pieces started to crack under the effect of the blades. Since the bar is 1 m long and the angle is small, it is then sufficient to approximate the torsional moment using the following relationship :

$$Mt = M * g * 1$$

Figure 11 : Picture of the experiment

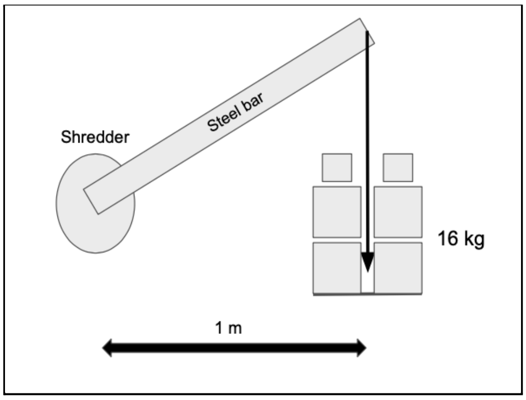


Figure 12 : Diagram of the experiment

With this simple approximation method, we find a necessary torque at the shredder inlet of at least **200 N.m**. Searching the internet for people who have also made this model of shredder, we have found that for it to work optimally, the input motor must develop a torque of **300 N.m**. We therefore choose this value as the maximum input value.

Choice of the new motor :

We have chosen the **CM90 I40 D35 3KW IE2 B14** :

Figure 13 : Picture of the new motor

-The output speed at the gearbox is **70 rpm**, which is the value recommended by the precious plastic website for shredding;

-The maximum output torque would be **327 N.m (**The torque obtained remains below the maximum admissible value (calculated before)

-The output diameter is **35 mm** as the diameter of the input shaft of the shredder, so the coupling will be easier to make later.

<u>Torsion limit calculation (D=0.025m):</u>

The diameter of the shaft is initially of 20 mm at the input of the shredder but the section is thicker at the blades section : it is a hexagonal bar of 28 mm width in steel which has been machined on both ends to a diameter of 20 mm to ensure the passage of the bearings. To simplify our calculations, we will take a 25 mm diameter shaft with a constant thickness (D = 0.025m):

$$I0 = \frac{\Pi D^{4}}{32} = 3,8.10\text{^}{-8} \qquad RgSteel = 150\,Mpa$$

We take a security factor of 2 to oversize and ensure good reliability.

Torsion limit (safety factor s=2) : $\Gamma = RgSteel/s$ **, so :**

$$Mt = RgSteel * I0 * \frac{2}{D} = 230\,N.m$$

The maximum acceptable torque at the shredder inlet is therefore **230 N.m** under these assumptions. This value therefore appears to be limiting.

To ensure a huge torque transmission and reliability over time, we decided to change the principal axis with a 40 mm hexagonal steel bar instead of the 28mm original hexagonal bar. We have chosen a 40 mm hexagonal bar because it was the simplest size to order by the school but also the size allowing us to have a shaft of diameter 35 mm identical to the engine that we chose thereafter. So we also had to cut new knives adapted to this new bar and to change the bearing supports.

<u>New torsion limit calculation (D=0.035m):</u>

$$I0 = \frac{\Pi D^{4}}{32} = 14.7.10\text{^}{-8} \qquad RgSteel = 150\,Mpa$$

Torsion limit (safety factor s=2) : $\Gamma = RgSteel/s$ **, so :**

$$Mt = \Gamma * I0 * \frac{2}{D} = 630\,N.m$$

The maximum acceptable torque at the shredder inlet is more than 600 N.m under these assumptions. This gives us room to manoeuvre to develop the system over time and the mill shaft will not be a limiting factor. The future motor will therefore be able to deliver more than 300 N.m without risking damage to the shaft. After machining, we obtain the new following parts (***Figure 14***) :

Figure 14 : New shaft, knives and bearings of the shredder

Coupling solution :

For the coupling, we have two options: to buy or to manufacture. Regarding the tools available, we decided to manufacture it ourselves. Ideally, for this type of shock-prone machine, a flexible coupling would be more suitable. However, making it would be too complex for us, so we decided to make a rigid coupling with two parts that fit the shape of the two shafts, a model can be seen below (***Figure 15***):

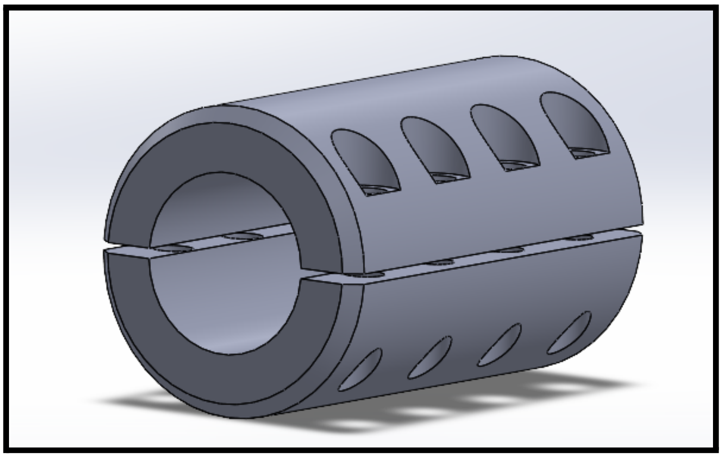


Figure 15 : Coupling joint

A 60 mm steel shaft would be bored to a 35 mm diameter and then cut off along its axis to separate the part into two. After that, a drawing and the various drillings - tappings on each of the two parts will be machined with a numerical control machine.

This kind of coupling is quite simple to do regarding the machines we have at our disposal, moreover, clamping can be adjusted to mechanically disengage the coupling when torque value is too high. This would not have been possible with a standard keyed coupling and would also have led to matting due to shocks during shredding.

Trolley modifications :

In the previous deliverables, we were also talking about reinforcing the support structure of our workbench, supporting the shredder assembly and the motor, actually made of a **30 mm** MDF wooden plate. This idea was quite rushed and our professors asked us to prove the necessity of changing this plate, so now we do :

The system we have, transmits high torque by the upper plate of the table, the reason why is that the motor and the shredder are two independent parts so they must necessarily be attached to a common support : the wooden plate. We would not want it to break under the effect of the engine torque so we decided to make a small simulation of the situation, described on **(figure 16)** below :

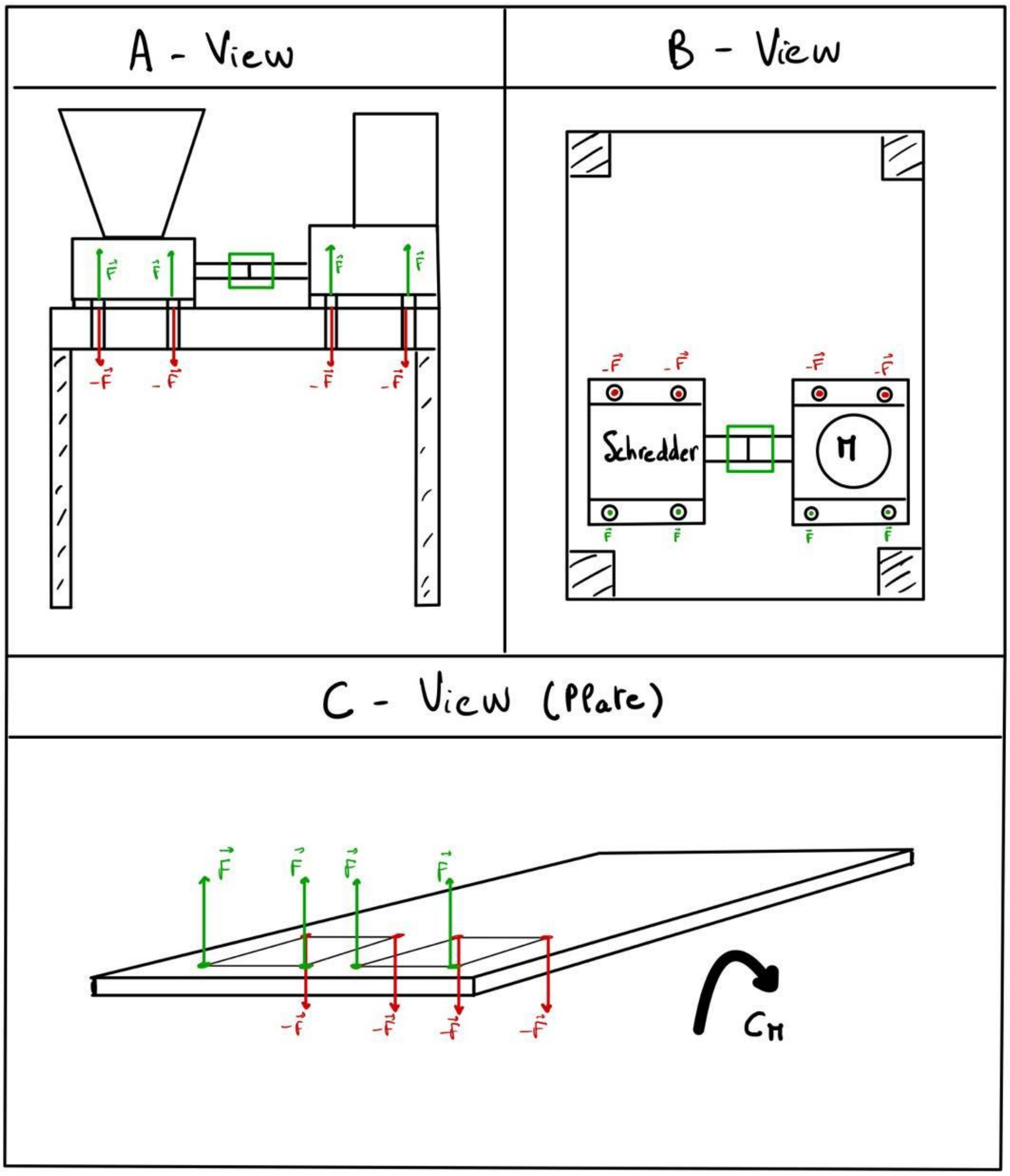
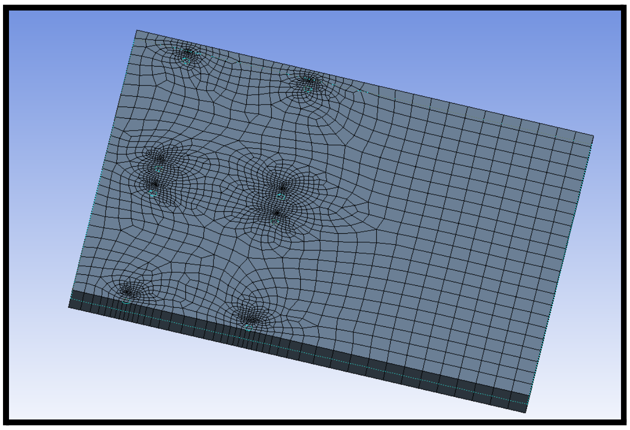
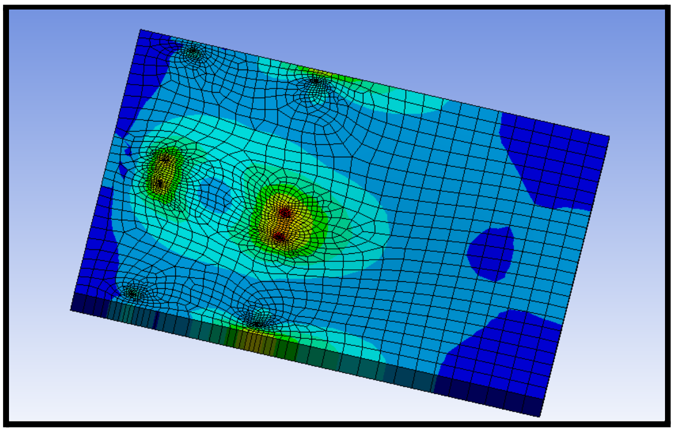


Figure 16 : Representation of the efforts due to engine torque

Now we have a simple but realistic schematic of what will really happen on the plate. We can get further into it by modeling this schematic on a structural calculation software, here we will use ANSYS Workbench.

By assumption, we are considering that the torque is equally distributed in the **8** fixation points, we also make the hypothesis that the radius of the blades is about **8 cm**. If we take a torque of **300 N.m** (maximum transmitted torque), we obtain ***(300/0,08)/8 = 470 N*** on each hole of fixation.





Caractéristiques techniques (valeurs moyennes des panneaux)			MDF
Spécifications	**Norme**	**Unité**	
Densité *	EN 323	kg/m³	570 - 720*
Résistance à la flexion	EN 310	N/mm²	15 - 23
Résistance à la traction, surface	EN 311	N/mm²	1,0
Module d'élasticité	EN 310	N/mm²	1500 - 2400
Teneur en humidité	EN 322	%	4 - 10
Émission de formaldéhyde	EN 120		E1
Tolérance épaisseur	EN 324-1	mm	± 0,2
Tolérance dimensionnelle	EN 324	mm	± 5
Conductibilité thermique λ	EN 12524	W/m.K	0,15
Teneur en PCP	EN 13986	ppm	< 5
Classe incendie	EN 13501		D
Résistance à la traction, perpend	EN 319	N/mm²	0,45 - 0,70
Gonflement après 24h. (18 mm)	EN 317	%	< 16

* Densité différents types de panneaux MDF: 560-620 = L-MDF / 650-670 = MEDIUM MDF / 720 = ST

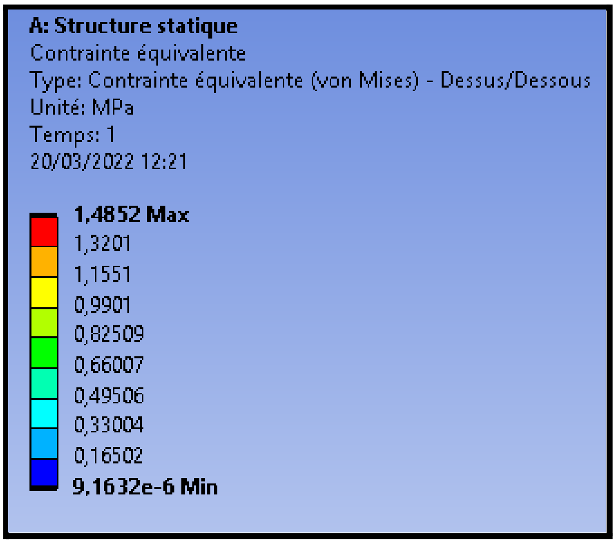


Figure 17 : Resistance of MDF wood [decopan.com]

As we can see, the maximum constraint is about 1.5 Mpa on the wooden plate, regarding **(Figure 17)**, MDF can absorb around 20 Mpa of bending so the plate seems solid enough to support all these efforts.

After these calculations, we kept in mind to reuse the existing wooden plate. The next step was to create a lower compartment allowing the storage of the chips and the installation of the electrical parts. Two 40x40 mm square tubes were welded to the workbench and a sheet of metal was placed and screwed between them to form the floor. We then cut and installed a front panel with the following elements: **emergency stop - circuit breaker (fuse) - start switch - speed control potentiometer**.

At the back of this front panel is located the electrical converter and the wiring. The whole is protected by a plexiglass plate preventing the user from putting his hands in the electrical compartment and the steel structure is electrically grounded. The final result is shown in **Figure 18** below:

Figure 18 : Front panel structure

E/ Data management for next year

In this project we have collected big quantities of data from different sources. For example we have started the project with a lot of documents provided by Guillaume Marin. We have also acquired different knowledge in the different meetings at FabMSTIC or with Manuel François. We also create a lot of data during our experiments with mesures, design or calculations.

Moreover this project is minded to be open source so all the data we had created had the goal to be public and accessible to anyone. That's why the group had chosen to put in place a repository on **github** where all the data we made are available and updated with the progression of the project.

In this GitHub wich can be found on the address https://github.com/clavelma/shredder_v2, it is possible to find, the picture of the prototype, the CAD files made or used by the team, the analysis of needs, some datasheet of different components we had. At the end of the project the Git-Hub will gather all the data we made during this project.

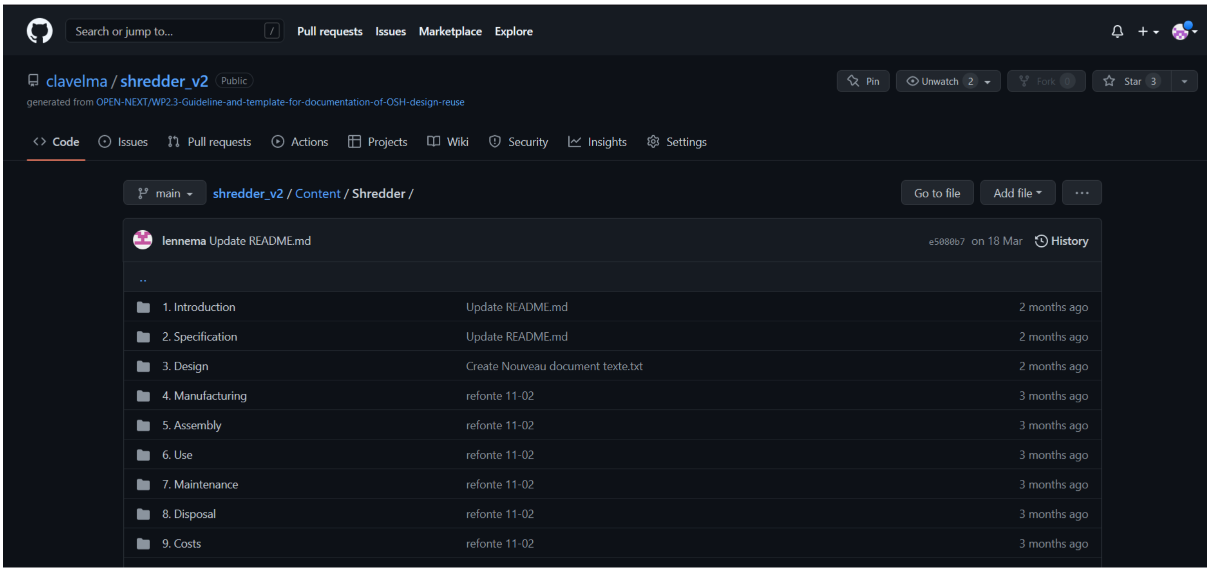


Figure 19 : The shredder and it's hopper

The choice of GitHub was made for several reasons, the first one was about the possibility to share to everyone our work and the details of the project for the open source community. The platform is pretty easy to use for consulting as well as to put documents online. Another reason is because GitHub was made to collaborate on projects and it became for the group a tool to work together and share the documents between us.

If this project had the chance to continue next year, the new group will be able to find all the data they need including some interesting starting point on others developpement for the project like a hot press to make plastic plates or to think about a supply chain to organize a whole plastic recycling solution.

Part 2 - PROJECT MANAGEMENT PART

A/ Organization of the group and organization of relations with the client

Our project group is composed of 6 people. Each of them has a specific role. We have :

- **The project manager :** responsible for the team in charge of the preparation, implementation and completion of the project.
- **The data manager :** in charge of acquiring and organizing all the information necessary for the smooth running of the project
- **The functional manager :** He carries out the overall operations necessary for the preliminary study, implementation and completion of the project. He must ensure that the solution created by the project functions correctly in relation to the needs defined by the client.
- **The technical manager :** his role is to manage the production and technical aspects of the project.
- **The technical support :** he supports the technical manager
- **The safety and environment manager :** he evaluates the risks and ensures that the impact of industrial activity on the environment is reduced.

Ressources used			
First name	**LAST NAME**	**Role**	**Initials for the Gantt**
Tom	BIANCIOTTO	The technical manager	TB
Maxime	CLAVEL	Data manager	MC
Louis	GASTON	Functional manager	LG
William	LEGARDEUR	Technical support	WL
Margaux	LENNE	Project manager	ML
Nsongurua Innocent	WILLIE	Safety and environment manager	WNI

Figure 20 : Composition of the group

Each person is allocated tasks on the Gantt chart. It is then up to them to organize themselves with the other people who are in charge of the same task in order to know who does which subtask or how to do it together. In order to easily access the tasks allocated to us and to follow their progress, we decided to use the **To Do application/website** which allows the team leader to enter all the Gantt tasks each week in the form of a list of tasks allocated to each person and shared in real time with the whole team. As a result, we get a simple, multi-platform way of keeping track of the project's progress, but also of consulting it, since this space is shared and the application can be downloaded to phones.

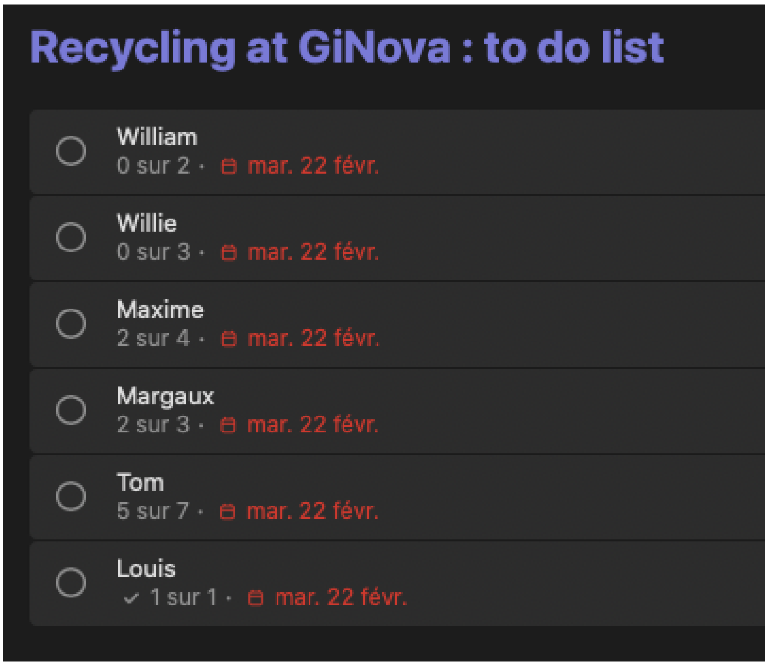


Figure 21 : Current tasks of group members on To Do

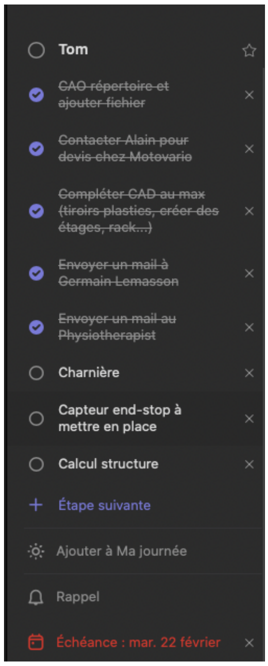


Figure 22 : Example of what a group member have to do

Concerning the documents shared within the group, this subject has been developed in more detail in part E/ Data management for next year. But let's just remember that we use the **Github platform** to store the different documents we used for our research and for the development of the product. This platform also allows us to write our own documents in open source, so they can be used by people outside the project and give them advice.

Finally, concerning the client, we kept him regularly informed of the progress of the project by e-mail, detailing what had happened since the last e-mail and attaching photos. When we needed more precise and urgent clarifications, we made an appointment with him and went to see him on campus at FabMSTIC to be able to talk more easily and directly.

B/ Planning of tasks carried out during the year

In order to follow the progress of the project we kept and updated a Gantt chart throughout the year. This Gantt created on a google sheet shows the tasks to be carried out, their duration and the resources allocated to them (6 in our project). We also find in separate sheets the subtasks of each task and their level of progress. During the 31 weeks of the project, this diagram has been revised 4 times and we will explain the reasons for this in the next section. In this section I will present the latest revision : G14_Gantt_REV.4.

As you can see in the extracts from the Gantt chart below, there are 18 tasks in the Gantt chart. Each of these tasks has different durations and resources. Some of them are more critical than others being on the critical path (red box in the figure below). Concretely this means that we had to pay special attention to these tasks because their delay directly impacts the final completion date of the project.

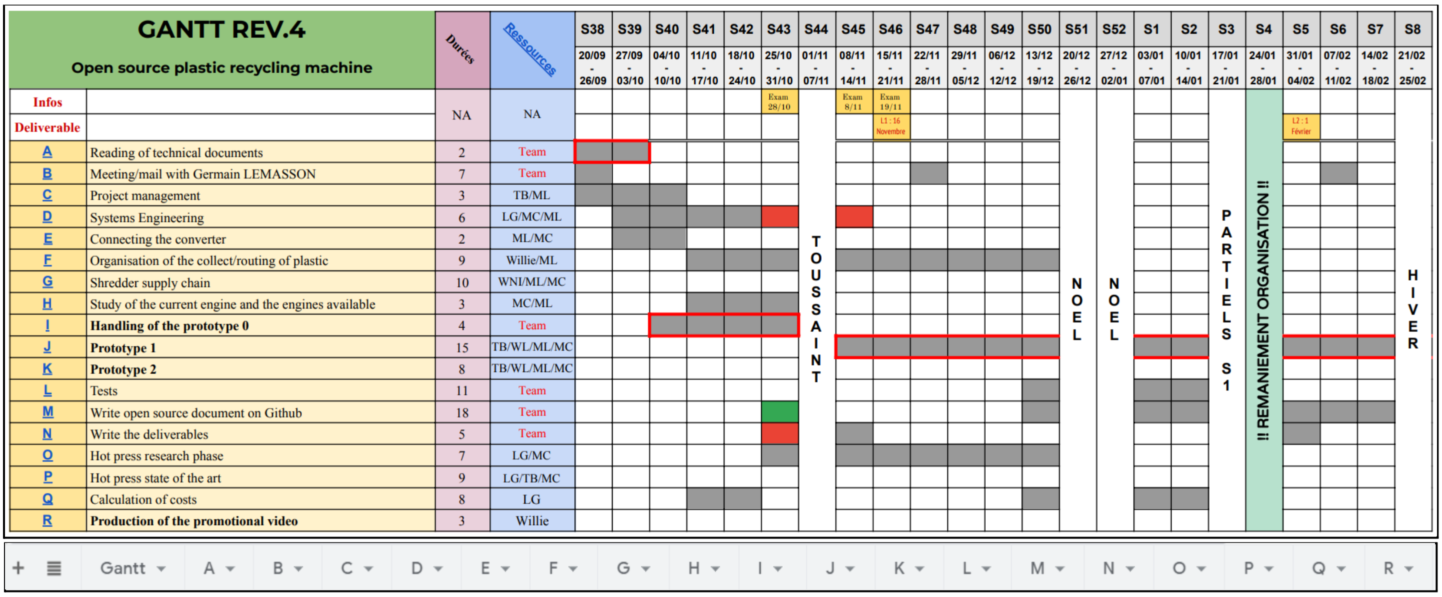


Figure 23 : Extract 1 of the gantt revision 4

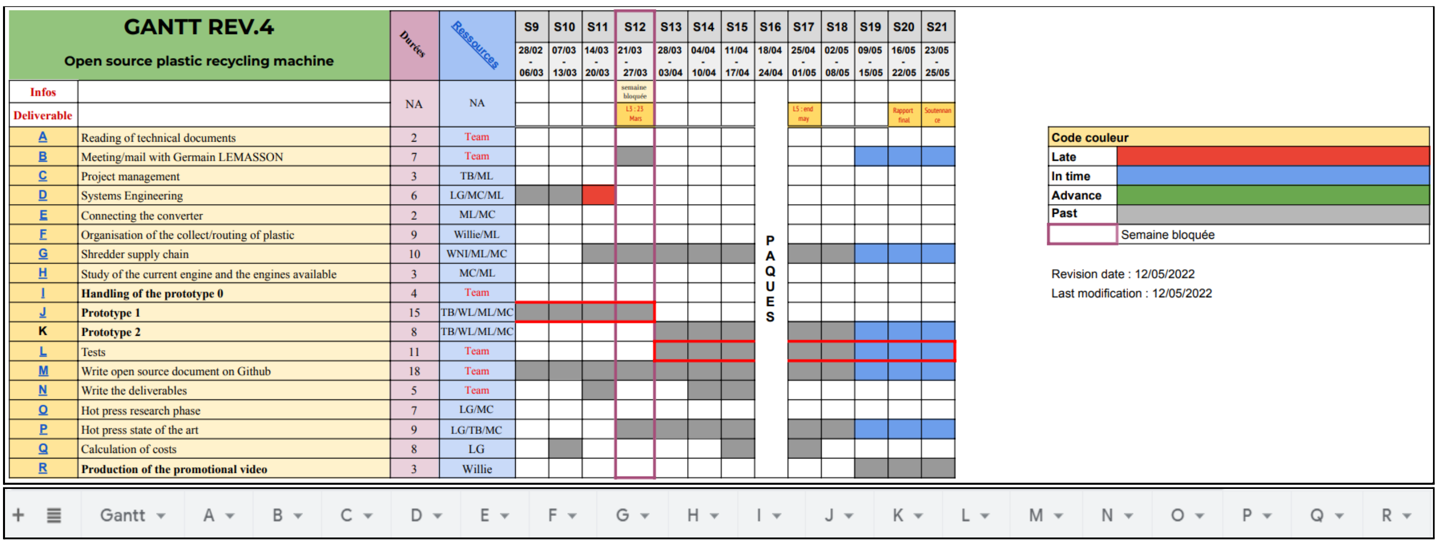


Figure 24 : Extract 2 of the gantt revision 4

Let's look in more detail at the flow of these critical tasks. There are four of them in our project:

- Task A - Reading of technical documents
- Task I - Handling of the prototype 0
- Task J - Prototype 1
- Task L - Tests

Task A "Reading the technical documents" corresponds to the first two weeks of the project and therefore to the period of appropriation of the subject. It was during these first weeks that we met the client for the first time in order to understand the main problem he was encountering at FabMSTIC, namely a professional shredder hopper that was too small, which obliged him to spend time pre-cutting all the plastics to be shredded "by hand". We were thus able to understand what he wanted from us and thus start thinking about the specifications.

This was followed by the other phase of appropriation of the subject with the critical *task I* "Handling of the prototype 0". Indeed, as explained in the part A/ Context of the study - Main objective of the project, Guillaume MARIN, an engineer, gave us a first prototype of a shredder which was not completely finished and which still needed to be improved. We called it prototype 0. We then had to take time to understand how it was made and how it worked. We identified the different elements of this prototype 0, analyzed forces on the blades, stresses on the teeth and decided what we would keep, discard and improve.

Once these two critical tasks were finished, we were in the 'Toussaint' period. This is when we started the implementation part of the project with the critical *task J* "Prototype 1". This is the most important task of the year and the longest one because it concerns the realization of our first prototype, the goal being that it should be operational at the end of the blocked week which took place from 21 to 27 March. To do this, we used the basis of the prototype 0 and improved it by concentrating especially on the safety aspect. The subtasks of this task and their level of progress are detailed in the figure below (everything is green because at the time of writing this deliverable this task is completed) :

J- Prototype 1

Tâche J.1	Securise the shredder with a hopper	
Tâche J.2	Install a cover	
Tâche J.3	Install the electrical box	
Tâche J.4	Install the end/stop button on the hopper	
Tâche J.5	Make the front of the electrical box	
Tâche J.7	Install the geared motor	
Tâche J.8	Adjust the modes on the converter	
Tâche J.9	Make the engine support	
Tâche J.10	Install a grid under the shredder to make big plastic chips	
Tâche J.11	Design a bin (bac) for the big ships of plastic	
Tâche J.12	Make the bin	

(red)	Not started
(yellow)	In progress
(green)	Achieve

Link to return to the Gantt : Gantt

Figure 25 : Extract of the subtask J

During this period we also started to write open source documents, which corresponds to the non-critical *task M* "Write open source documents on Github" (This part on open source documents is detailed in part 1 : E/ Data management for next year.)

The end of the blocked week marks the end of the critical task on the realization of prototype 1. We then started the last critical task of the project which concerns the tests : *task L* “Tests”. The purpose of these tests is to validate or not the various specifications of the specifications and were developed in the section C/ Presentation of the product and its suitability for the need expressed. In parallel with this last critical task, we also improved prototype 1 by making a prototype 2 with a more powerful motor, a stronger shaft, new bearings, and new knives. At the time of writing this deliverable, we have only two weeks left to focus on completing the testing and (hopefully) the completion of prototype 2.

C/ Analysis of deviations between planning forecasts and actual planning

In order to carry out such a project properly, one of the first steps is to make a Gantt chart like the one we have just presented to you for our project. It allows us to monitor the progress of the project and check that tasks are not taking too long to complete. As we explained in the previous section, several revisions of this Gantt chart were made this year. Now that we are at the end of the project, we can do a review by analyzing the reason for these revisions and thus analyze the differences between the planning and the actual planning.

- **From revision 1 to revision 2 of the Gantt**

Let's start by analyzing the reason for the change from revision 1 to revision 2 of this Gantt. This revision took place just before the 'Toussaint' holiday. Indeed, if we take a closer look at Revision 1 (an extract of this revision can be found in the figure below) we can see that there was a delay in installing an emergency stop button, a potentiometer and a forward/reverse button. The project manager realized at this point that the individual tasks in the Gantt were too specific and that it would be better to make a schedule for more general tasks. He therefore decided to write down the different sub-tasks for each task in separate excel sheets, tracking their progress by color coding. This allowed people in charge of a task to better manage their time so that they could do a subtask when it suited them over a long period of time rather than having to do them absolutely within a short period of time. The key is that at the end of the overall task, all subtasks are completed.

GANTT REV.1		Durées	S38	S39	S40	S41	S42	S43	S44
			20/09-26/09	27/09-03/10	04/10-10/10	11/10-17/10	18/10-24/10	25/10-31/10	01/11-07/11
Infos partiels		NA						Exam 28/10	
Infos livrables									
A	Read the given documents about plastic and machines	2							
B	Meet the client, Germain LEMASSON	1							
C	Meet the physiotherapist	1							
D	Specifications and architectures	2							
E	Make the requierments chart (one group)	1							
F	To make the engine works	3							
G	Organise the collect of the plastic with the RAFU network	3							T
H	To study the engine characteristics and see if we have to change it + Find a new one necessary	3							O U S
I	To securise the shredder with a hopper and a cover	3							A
J	To install emergency button, external potentiometer and forward/backward switch	2							I N
K	Make some tests with Germain Lemasson	1							T
L	Realise the housing (carter)	2							
M	Make the engine support	3							
N	Design a bin (bac) for the big ships of plastic	1							
O	Make the bin	1							
P	Make final tests	1							
Q	Write all document about the shredder (safety rules, working, ...)	2							
R	Write the deliverable n°1	1							

Figure 26 : Extract of the gantt revision 1

● **From revision 2 to revision 3 of the Gantt**

Now let's look at the reasons for the creation of Revision 3. We have an extract from Revision 2 below. We can see that since the creation of Revision 2 just before All Saints Day, Task E "Systems Engineering" which corresponds to Task D "Specifications and architecture" of REV.1 started to fall behind. This corresponds to the period when we lost our way in the project, not understanding the expectations. However, we managed to recover by focusing on the initial problem encountered by our client. Furthermore, this delay did not impact the project greatly as it was not a critical path task. However, this was not the case several weeks later. Indeed, we were too optimistic in wanting to finish the shredder prototype by Christmas in order to start the compressor prototype just after the holidays. Of course this was not the case and this time a critical path task was impacted. As soon as a critical path task falls behind, this has a direct impact on the final project completion date. As we could not postpone the final completion date of the project, we had to meet again to discuss the expectations of the project. We realized that what really mattered was the realization of a working prototype of a low-tech shredder and that it was overestimating ourselves to think that we could also realize a prototype press. So we agreed to concentrate on the shredder and to give ourselves more time to complete the prototype. So we removed the task of making the compressor prototype but we still created a task to at least do the state of the art of the compressor.

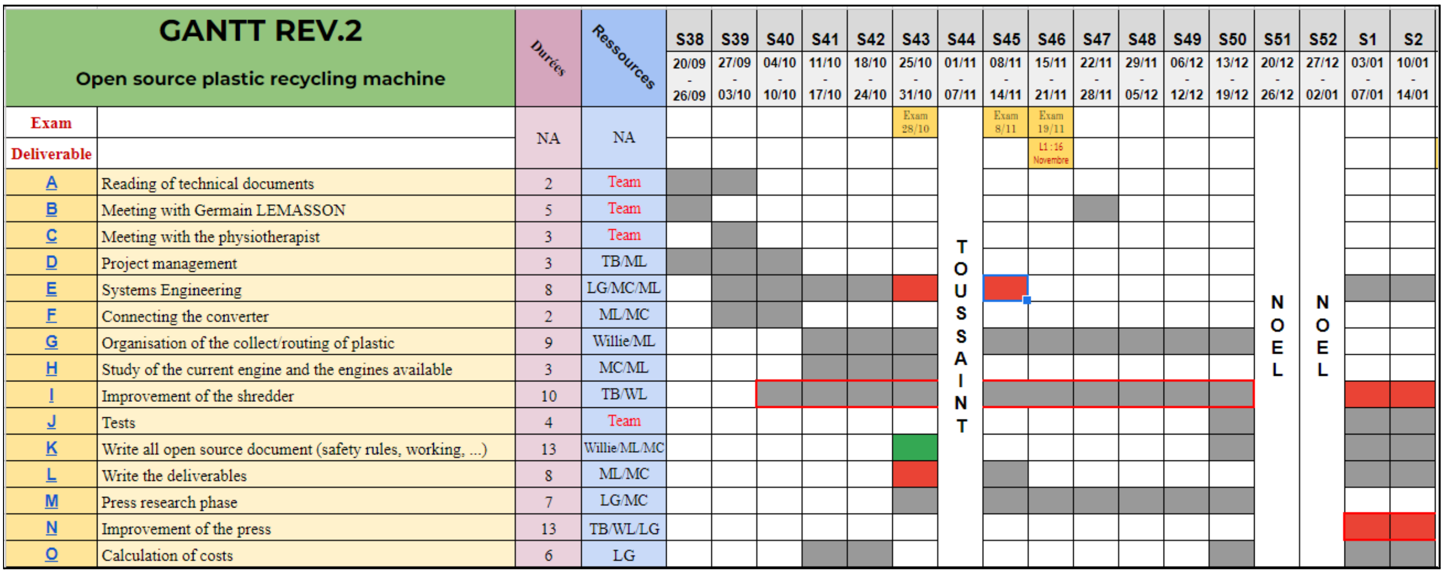


Figure 27 : Extract of the gantt revision 2

● **From revision 3 to revision 4 of the Gantt**

Finally, let's talk about the reasons that led to the creation of the last revision of the Gantt, which is the revision that was developed in the previous section. This again concerns a delay on a critical path task. Indeed, we had obtained a working prototype but it did not meet all its objectives because the motor was not developing enough torque. We ordered a new motor but it was late in being delivered and has still not arrived at the time of writing. Undoubtedly, Task I "Improvement of the shredder" has started to fall behind. As this delay was on the critical path, it risked delaying the entire project. As with every major problem encountered this year, we held a group meeting to discuss it. This was another opportunity for us to take stock of what we have done in the last few weeks, what still needs to be done and what the project really needs. We then realized that a crucial stage of the project was the "test" part to validate the specifications. Now, having a functional but not optimal prototype, we were able to carry out these tests thanks to the chips obtained by crushing the supports of 3D printed parts. The improvement of the shredder with the new motor was therefore only a plus for the project and could be seen as a second, non-critical prototype version. By mutual agreement, we drew up the last revision of the Gantt chart taking into account this reflection. This revision consisted of differentiating between the different prototype versions and emphasizing the test part.

GANTT REV.3 Open source plastic recycling machine		Durées	Ressources	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21
				28/02 - 06/03	07/03 - 13/03	14/03 - 20/03	21/03 - 27/03	28/03 - 03/04	04/04 - 10/04	11/04 - 17/04	18/04 - 24/04	25/04 - 01/05	02/05 - 08/05	09/05 - 15/05	16/05 - 22/05	23/05 - 25/05
Infos		NA	NA				semaine bloquée									
Deliverable							L3 : 23 Mars					L5 : end may			Rapport final	Soutenance
A	Reading of technical documents	2	Team													
B	Meeting/mail with Germain LEMASSON	5	Team													
C	Project management	3	TB/ML													
D	Systems Engineering	7	LG/MC/ML													
E	Connecting the converter	2	ML/MC								PAQUES					
F	Organisation of the collect/routing of plastic	9	Willie/ML													
G	**Shredder supply chain**	8	WNI/ML/MC													
H	Study of the current engine and the engines available	3	MC/ML													
I	Improvement of the shredder	21	TB/WL/ML/MC													
J	Tests	7	Team													
K	Write open source document on Github	16	Team													
L	Write the deliverables	4	Team													
M	Hot press research phase	6	LG/MC													
N	**Hot press state of the art**	7	LG/TB/MC													
O	Calculation of costs	7	LG													

Figure 28 : Extract of the gantt revision 3

D/ Project risk analysis: the year in review

We had reached a conclusive point in our project at a reasonable time. Over the past three weeks, we have been awaiting the arrival of the new motor for the shredding machine. During this waiting time, we have made changes to both the design of the shredder and progressive changes to the risk analysis.

Starting with adjusting the risk analysis, the risks were classified into two parts (as you can see below), "project management risks" and "utilization risks". The project management risks are risks that concern the output of the project as pertaining to the team and the client. The utilization risks are risks affecting the use of the shredder, like injury occurrence, inability to use a shredder, etc. This will really help in having a clear understanding of the risks even at first glance. One can identify the risks that are peculiar to his situation.

The risks were graded based on the assumptions of the level of risk, on the range of 1 to 3. 1 for "low risk", 2 for "average risk" and 3 for "highest risk". The risks with high levels of criticality are in red, for emphasis.

1. Project management risks

Risk family	Risk	ID	Description	Severity (1 to 3)	Occurence (1 to 3)	Criticality (E*F)	Action taken to avoid the risk
Communication	An oversight of client requirements	1.1	The customer expected something different to what we produced or want something different without telling us ahead	3	1	3	Maintain regular contact with customers (not just virtually)

Figure 29 : Extract of the risk analysis

2. Utilisation risks

Risk family	Risk	ID	Description	Severity (1 to 3)	Occurence (1 to 3)	Criticality (E*F)	Action taken to avoid the risk
Security	A user is injured by the shredder	2.1	A user may be cut by the blades if he does not respect the security chart and other injuries can occur.	3	1	3	Print precise rules of use and put them near the machine

Figure 30 : Extract of the risk analysis

While working on making changes to the risk and waiting for the new motor, some changes were made to the shredder itself. Firstly, we added an additional plate (sliding) to the up of the hopper. This is to prevent any mistake from users of the shredder who will mistakenly put their hands inside the shredder.

Most importantly, the blades of the shredder were changed to one with different dimensions and this improved the performance of the shredder significantly. The dimensions were bigger as compared to the former, the accompanying rod had to be changed also.

As a result of having a substantial motor for the shredder, the flexibility of carrying various tests with different sizes of grid is not possible, as this would have given us multiple choices. So far, we are satisfied with the sizes of plastic chips obtained and it is certain that our client can shred it comfortably and make filaments from them.

Environmental safety was of course paramount, in this case, the shredder does not give out any fumes as compared to a compressor. The possibility of the shredder plastics splashing out during the process is quite low, thanks to the cover of the hopper. Moreover, only specific plastics should be shredded for the purpose of making the filaments. Hence, future hazards that can be created as a result of combining different varieties of plastics.

E/ Project cost analysis: overall balance

As for the costs, Guillaume Marin sent us an excel file where the costs of his work were listed (see appendix). We then completed this cost analysis by adding everything we were doing: the raw material (metal for the hopper), the new gear motor, the electronic parts, but also the machining and manufacturing costs, the finishing costs and finally we added the operator, engineering and machine costs.

For all the parts, and activities, that we added or modified in our mill, we looked for their corresponding price in order to be able to calculate the final cost of our prototype. However, many of them were given to us, which makes them salvageable and therefore something to be taken into account in the final cost calculation as many parts can be salvaged. This would reduce the costs considerably such as the trolley we use as a structure.

Finally, we have quantified the machine, operator and above all the engineering costs. For the machines, we calculated their hourly rate and estimated the time spent on them (with adjustments as this is not a mass production project...). Then, for the operator cost, we multiplied the average hourly rate of an operator in France by the time we spent on "industrial" machines, such as the lathe or the waterjet cutter for example. Indeed, as the aim is to make it a personal project, we estimate that the person who will make this shredder will have a minimum of tools and will therefore be able to do certain elementary operations without having at his disposal the big machines that we can have in companies or fablab for example. We also calculated the engineering cost of our project, i.e. the cost of the work of the six of us, at the rate of approximately 4 hours per week, multiplied by the average hourly rate of an engineer.

The final budget for our project is about 30 000€. This sounds like a lot, but if we remove the engineering costs, it is about 2 250 € and as we said before, many parts can be recovered, besides the gear motor part, which costs almost 900€, i.e. 40% of the total price, there is a large part of the electrical part (potentiometers, end stop sensor...). Also, we have put a lot of emphasis on safety on our product, which increases the costs considerably. Indeed, just the yellow LED flashing light costs 225€, i.e. 10% of the price, but also the circuit breaker in case of emergency stop or other component problems for example.

APPENDIX : Cost table

Parts		1 879,23 €
	Mechanical parts	217,63 €
	Electric parts	774,41 €
	Motorisation	887,19 €
Machining		147,05 €
Ingeneering		28 800,00 €

Description	Material	Price	Details	Quantity	Where to get it
Machine parts					
3mm pieces	*Steel*	- €		1	*IUT Joseph Fourier - Gre*
5mm pieces	*Steel*	133,28 €		1	http://www.oxytemps.f
6mm pieces	*Steel*			1	
Screw	*Steel*	- €	*M6 x ??*	8	
Nut	*Stainless*	- €	*M6*	8	
Washer	*Stainless*		*M6*	8	
Hexagonal bar	*Steel*	6,92 €		1	https://www.acier-deta
Bearing		22,01 €	*UCFL204 Ø20mn*	2	https://www.123roulen
Screw	*Stainless*	3,10 €	*M10 x 60*	4	*Neton*
Nut	*Stainless*	2,17 €	*M10 6 pans*	4	*Neton*
Threaded shaft	*Steel*	1,95 €	*Ø10 - 25cm*	2	*Mon brico*
Nut	*Stainless*		*M10 6 pans*	4	
Motor/Shaft connector	*Steel*	2,50 €	*Ø60mm L60mm*	1	https://www.acier-deta
Screw	*Stainless*	- €	*M8 x ??*	2	
Structure	*Steel*	- €		1	*Ancien portail*
Angle profile	*Steel*	- €	*30*30*3mm*	2	
Washer	*Stainless*	- €	*M10*	16	
Screw/Shaft	*Stainless*	- €	*M10 x 50*	4	
Nut	*Stainless*	- €	*M10*	8	
Screw	*Stainless*	- €	*M8 x ??*	3	
Nut	*Stainless*	- €	*M8*	3	
Washer	*Stainless*	- €	*M8*	3	
Mesh sheet	*Steel*	0,50 €	*1<Ep<2mm*	1	*Arc-en-ciel*
Sheet metal for hopper	*Steel*	35,20 €	*1<Ep<2mm*	2	https://www.leroymerl
Plastic filament	*Plastic*	10,00 €	*200 gr*		
3m hex bar	*Steel*	133,00 €	*3m*	1	
Bearings		50,00 €		2	
Structure		*Récup*		1	
Gear Motor					
Gearmotor		839,53 €		1	
Electronics					
3 Poles male plug + Earth		14,75 €		1	https://www.leroymerlin.fr/v3/p
3-position switch contactor		7,32 €	*on-off-on 15A/25*	1	https://www.manomano.fr/p/in
Female flat terminal		- €	*6,3 x 0,8mm*	6	
Electrical Cable		- €			
Electronic box		- €			
~~*Permanent capacitor*~~		~~10,32 €~~	~~*20 µF à câble*~~	~~1~~	~~https://www.condensateu~~ ~~https://www.astuces-prat~~
End-stop sensor		24,23 €		1	https://fr.rs-online.com/web/p/c
Yellow LED flashing light		225,15 €	24 V CA CC -IF	1	https://www.se.com/be/f
Emergency stop button		23,60 €		1	https://fr.rs-online.com/w
Potentiometer		10,00 €		1	
Circuit breaker		81,68 €	*2 poles C60N*	1	https://fr.rs-online.com/w
Converter		377,36 €		1	https://fr.rs-online.com/w
Machining					
Screw head		- €			*GENOVA Phiphi*
Bearing spacer 3mm	*Plexiglass*	- €			*GENOVA Phiphi*
Hexagonal bar		- €			*GENOVA Phiphi*
Motor/Bar connector		- €			*GENOVA Phiphi*
Drilling Motor/Bar/Connector		- €			
Tapping (Thread)		21,25 €			*Mon Brico*
Grinding structure		- €			
Welding structure		50,00 €			*Remorque mandrinoise*
Water jet cutting hopper and blades		-			*ENSE3 Fablab*
Hopper folding		-			*GInova*
Welding		-			*GInova*
Turning		-			*GInova*
Laser cutting					
3D printing		-			*FavLab*
Finishing					
Sanding + Disc		- €			
Rustproof paint		14,50 €			
Machine costs:					
Water jet cutting		16,00 €		1h20min	
3D printer		1,30 €		2h	
lathe		64,00 €		1h20min	
Laser cutting		0,42 €		5min	
Operator costs		70,00 €		2h20 (Découpe + pliage + tour)	
Ingeneering costs		28 800,00 €		480,00	
TOTAL PROJECT		31 052,04 €			
TOTAL (without ingeneering cost)		2 252,04 €			