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**ESCUELA DE INGENIERÍAS  
INDUSTRIALES**

**UNIVERSIDAD DE VALLADOLID**

**ESCUELA DE INGENIERIAS INDUSTRIALES**

**Grado en Ingeniería Mecánica**

**Desarrollo y construcción de recicladora de  
ácido poliláctico (PLA) destinada a la  
impresión 3D**

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## TFG REALIZADO EN PROGRAMA DE INTERCAMBIO

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TÍTULO: Kaplock PLA Kruncher

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FECHA: 15/01/2019

CENTRO: Avans University of Applied Sciences

TUTOR: Willem Pennings, Adriana Quintero Ramirez.

## ABSTRACT

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The project given to Team D of the 2018 Fall EPS group was to develop a machine that would recycle old 3D printed parts, support structures, and failed prints into new filament to use in a 3D printer. The main reason why this project was carried out was that the company Kaplock B.V. produces an excess of PLA waste. To solve this issue, the team created a recycler that reduces the waste produced by the company. This was an important solution because it would allow Kaplock B.V. to save money and create a circular lifecycle for the PLA. The machine that Team D created receives PLA in the form of old prints, failed prints, or support structures. The recycler then crushes the parts into smaller pieces, so the PLA can be melted into liquid. This liquid plastic is then pushed through a nozzle to ensure a correct diameter that meets industry standards. The final step in the process is to coil the filament onto a spool so it can be reused in a 3D printer.

## KEY WORDS

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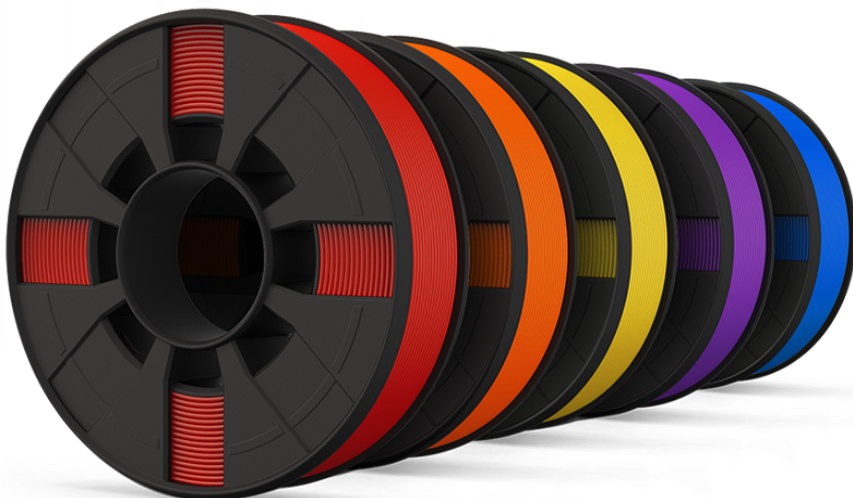
- PLA
- Kaplock
- Recycler
- Scrum
- European Project Semester (EPS)

EPS Final Report  
Kaplock B.V.

**Team D:**

**Dan Kordys David Adamowicz**

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## Table of Contents

Table of Contents .....	2
Foreword .....	4
Summary .....	5
List of Abbreviations.....	6
Glossary of Terms.....	7
Mathematical Symbol Index .....	10
Chapter 1: Introduction.....	11
Chapter 2: Kaplock B.V.....	13
Chapter 3: Project Description.....	14
Chapter 3.1: Project Boundaries and Scope .....	14
Chapter 3.2: Project Stakeholders .....	15
Chapter 3.3: Project Goals .....	15
Chapter 3.4: Project Management Methods .....	15
Chapter 4: Process of Work .....	16
Chapter 4.1: Research .....	16
Chapter 4.2 Testing .....	17
Chapter 4.2.1: Filament Testing .....	17
Chapter 4.2.2: Crusher Testing .....	18
Chapter 4.2.3: Angle Grinder Testing .....	19
Chapter 4.2.4: PID Tuning .....	19
Chapter 4.2.5 Blade Testing .....	19
Chapter 4.2.6: Motor Adapter Testing .....	20
Chapter 4.2.7: Filament Roll Counting .....	23
Chapter 4.3: Prototyping .....	24
Chapter 4.3.1: 3D Printing Issues .....	24
Chapter 4.4: Product Development .....	25
Chapter 4.4.1: Initial Designs .....	26
Chapter 4.4.2: Design Development .....	27
Chapter 4.4.3: Final Design .....	29

Chapter 4.5: Final Outcome .....	29
Chapter 5: Final Outcome .....	34
Chapter 5.1: Hopper .....	34
Chapter 5.2: Crusher .....	36
Chapter 5.3: Extruder .....	37
Chapter 5.4: Coiler .....	39
Chapter 5.5: Recommendations .....	40
Chapter 6: Final Product .....	42
Chapter 7: Conclusion .....	43
Chapter 8: Bibliography .....	44
Chapter 9: Appendix .....	46
Appendix 1: Fusion 360 .....	46
Appendix 2: Project Plan .....	49
Appendix 3: Motor Specification .....	53
Appendix 4: PLA Properties .....	58
Appendix 5: Adapter Failures .....	60
Appendix 6: Design Development Sketches .....	63
Appendix 7: Python Code .....	65
Appendix 8: Plexiglas Drawing .....	71
Appendix 9: Manufacturing Costs .....	72
Appendix 10: Precious Plastic Shredder Plan .....	73

## Foreword

This is the final report of the Kaplock project group. This team took part in the European Project Semester programme (EPS) organized by Avans Hogeschool of Applied Sciences in s'-Hertogenbosch (Netherlands). The team consisted of four students pursuing bachelor's degrees; a Polish student studying Product Design in Nottingham Trent University (United Kingdom), a German studying Industrial Engineering in Hochschule Augsburg, an American studying Mechanical Engineering in Michigan Technological University, and a Spanish member studying Mechanical Engineering in Universidad de Valladolid.

Since the members of the group were specialized in different backgrounds the distribution of tasks was straightforward, with each team member focusing on tasks that fit what they learned in their respective curriculums. This allowed the team to have a more equal distribution of the workload and a direct plan of approach.

The project group would like to thank the following individuals from Kaplock for their assistance, support and advice:

- Willem Pennings
- Dhargyal-Sebastiaan van Oorschot
- Job Trommelen
- Thijs van der Ven
- David de Prez

The project group would like to thank the following individuals from Avans University of Applied Sciences for finding a challenging and interesting project:

- Frans van Seggelen
- Adriana Quintero Ramírez
- Daphne van den Berg



## Summary

The project given to Team D of the 2018 Fall EPS group was to develop a machine that would recycle old 3D printed parts, support structures, and failed prints into new filament to use in a 3D printer. The main reason why this project was carried out was that the company Kaplock B.V. produces an excess of PLA waste. To solve this issue, the team created a recycler that reduces the waste produced by the company. This was an important solution because it would allow Kaplock B.V. to save money and create a circular lifecycle for the PLA.

The machine that Team D created receives PLA in the form of old prints, failed prints, or support structures. The recycler then crushes the parts into smaller pieces, so the PLA can be melted into liquid. This liquid plastic is then pushed through a nozzle to ensure a correct diameter that meets industry standards. The final step in the process is to coil the filament onto a spool so it can be reused in a 3D printer.

## List of Abbreviations

Table 1. Abbreviations

PLA	Polylactic Acid
CAD	Computer-aided Design
CAM	Computer-aided Manufacturing
FEM	Finite Element Method
B.V.	Besloten Vennootschap (Dutch private limited liability company)
3D	3 Dimensional
EPS	European Project Semester
PID Controller	Proportional–integral–derivative Controller
LCD	Liquid Crystal Display
SLA	Stereolithography
CNC	Computerized Numerical Control
DC	Direct Current
V	Volts
LED	Light Emitting Diode
AD Converter	Analog-to-Digital Converter
GPIO	General Purpose Input Output
PWM	Pulse-width Modulation
IP	International Protection Marking
ISO	International Institute for Standardisation
DIN	German Institute for Standardisation

## Glossary of Terms

**Stakeholder** - A person, group or organization that has interest or concern in a business. Stakeholders can affect or be affected by the organization's actions, objectives and policies. Not all stakeholders are equal. A company's customers are entitled to fair trading practices, but they are not entitled to the same consideration as the company's employees. Some examples of key stakeholders are creditors, directors, employees, government (and its agencies), owners (shareholders), suppliers, unions, and the community from which the business draws its resources.

**Scrum** - Scrum is a framework within which people can address complex adaptive problems, it allows the project team to innovate the product in a progressive way. Scrum implements the scientific *method* of empiricism. It replaces a programmed algorithmic approach with a heuristic one, with respect for people and self-organization to deal with unpredictability and solving complex problems. The infographic below, in Figure 1, gives us an overview of how Scrum works and explains the different parts.

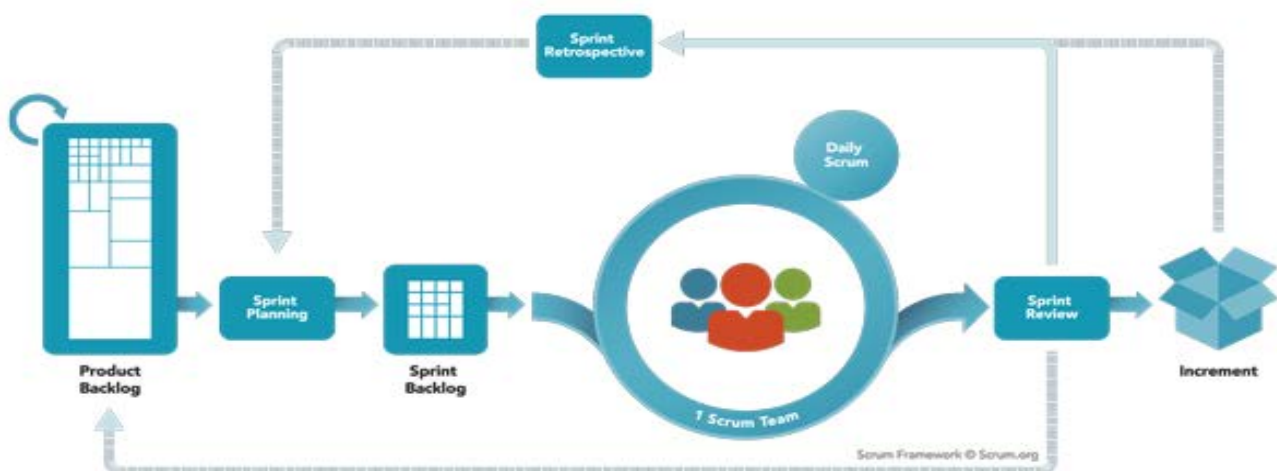


Figure 1. Scrum Framework

**Sprint** - A sprint is a time-box of one month or less during which a “Done”, useable, and potentially releasable product Increment is created. Sprints have consistent durations throughout the development effort of the product. A new Sprint starts immediately after the conclusion of the previous Sprint.

**Kaplock (product)**- The Kaplock is a product designed by Willem Pennings (the director of the company) which is a coat rack system that allows the customer to safely store their garments for 1 euro. The Kaplock is supposed to replace coat rooms as well as help tackle the problem of jacket theft. The Kaplock uses a steel cable threaded through the garment which locks it with the turn of a key.

**Gantt Chart**- It is used in project management and is one of the most popular as well as useful ways of showing activities (tasks or events) displayed against time in the project.

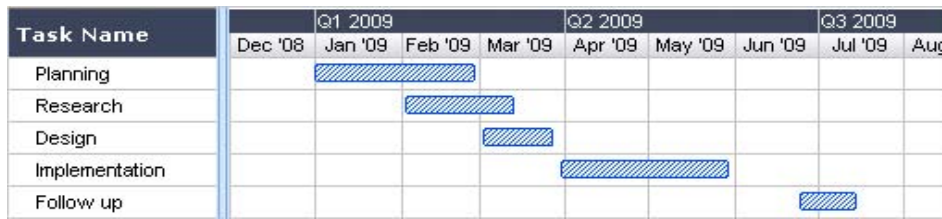


Figure 2. Gantt Chart Example

Figure 2 shows an example of a simple Gantt chart for visual reference, on the left of the chart is a list of the activities and along the top is a suitable time scale. Each activity is represented by a bar; the position and length of the bar reflects the start date, duration and end date of the activity.

**Work Breakdown Structure** - A work breakdown structure (WBS) is a key project deliverable that organizes the team's work into manageable sections. It visually defines the scope into manageable chunks that a project team can understand, as each level of the work breakdown structure provides further definition and detail. The project team creates the project work breakdown structure by identifying the major functional deliverables and subdividing those deliverables into smaller systems and sub-deliverables.

**PID controller**- Proportional-Integral-Derivative (PID) control is the most common control algorithm used in industry and has been universally accepted in industrial control. The popularity of PID controllers can be attributed partly to their robust performance in a wide range of operating conditions and partly to their functional simplicity, which allows engineers to operate them in a simple, straightforward manner. As the name suggests, PID algorithms consist of three basic coefficients; proportional, integral and derivative which are varied to get optimal response. The basic idea behind a PID controller is to read a sensor, then compute the desired actuator output by calculating the PID responses and summing those three components to compute the output.

**Raspberry Pi**- The Raspberry Pi is a low cost, credit-card sized computer that plugs into a computer monitor or TV and uses a standard keyboard and mouse. It is a very capable device that enables people of all ages to explore computing, and to learn how to program in languages like Scratch and Python. It's capable of doing everything you'd expect a desktop computer to do. The Pi is a very important tool when prototyping and its multifunctionality lends itself in a large variety of projects.

**Plexiglas**- Plexiglas is a plastic material made from polymers of methyl methacrylate, an ester of methacrylic acid. The technical name for this material is polymethylmethacrylate (or PMMA for short), but it also goes by many other trade names, such as Perspex, Acrylite, Acrylplast, Lymacryl, Lucite Acrivill, Altuglas, Perclax, Oroglas, Trespex and Vitroflex. However, its original and most famous trade name is Plexiglas. It is a great alternative to glass. That's why it's also known as acrylic glass and is one of the most widely used plastic materials. Unlike glass though, it is shatter-proof, very flexible and even more transparent (its transmittance factor is 0.93, while that of glass ranges between 0.80 and 0.90).

**PLA**- Polylactic Acid (PLA) is different than most thermoplastic polymers in that it is derived from renewable resources like corn starch or sugar cane. Most plastics, by contrast, are

derived from the distillation and polymerization of non-renewable petroleum reserves. Plastics that are derived from biomass (e.g. PLA) are known as “bioplastics. Polylactic Acid is biodegradable and has characteristics similar to polypropylene (PP), polyethylene (PE), or polystyrene (PS). There is a vast array of applications for Polylactic Acid. Some of the most common uses include plastic films, bottles, and biodegradable medical devices (e.g. screws, pins, rods, and plates that are expected to biodegrade within 6-12 months).

**Angle Grinder-** This is a hand-held power tool with a fast-rotating disk attachment used for grinding (abrasive cutting) and polishing. Even though the tool was originally developed for use with abrasive disks the availability of alternate power sources has encouraged a wide range of different cutting disks and attachments. Angle grinders are standard equipment in metal fabrication shops and on construction sites. They are also common in machine shops, along with die grinders and bench grinders.

**Pulse-width modulation-** This is a way of describing a digital signal (binary) that has been created through a modulation technique. Modulation is the process of varying one or more properties of a periodic waveform, called the carrier signal, with a modulating signal that typically contains information to be transmitted. Although this modulation technique can be used to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices, especially to inertial loads such as motors.

**General Purpose Input Output-** GPIO is a type of pin found on an integrated circuit that does not have a specific function. While most pins have a dedicated purpose, such as sending a signal to a certain component, the function of a GPIO pin is customizable and can be controlled by software. Not all chips have GPIO pins, but they are commonly found on multifunction chips, such as those used in power managers and audio/video cards. The Raspberry Pi. includes a row of GPIO pins along the edge of the board that provide the interface between the Raspberry Pi and other components.

**Stereolithography-** Stereolithography (SLA) is an additive manufacturing process that builds solid prototypes, patterns and products from CAD drawings. SLA enables the construction of solid plastic prototypes that are weaved from a CAD-powered laser beam gun. Like any other additive manufacturing process, creates a model in a layered approach. It uses liquid plastic or curable photopolymer to serve as the material for each layer. The ultraviolet laser draws the object onto the liquid surface layer by layer until all layers are completed. When a layer is finished, it is exposed to ultraviolet laser light that solidifies the layer and allows it to merge with the previous layer.

**FUSION 360-** Fusion 360 is 3D CAD reinvented to become the next generation Product Innovation Platform incorporating CAD/CAM/CAE tool for collaborative product development. Autodesk Fusion 360 is a fundamental departure from our current desktop bound CAD software, so let’s have a deeper dive and get a high-level overview of what really sets it apart from the competition, why the platform is such a compelling offering and how it helps ends users and businesses meet the requirements, challenges and technological changes facing the design and manufacturing sectors. More information regarding FUSION 360 can be found in Appendix 1.

## Mathematical Symbol Index

Symbol	Meaning	Explanation
k	kilo	Factor of 1000
m	milli	Factor of 0.01
c	centi	Factor of 0.001
u	micro	Factor of 0.000001
min	Minute	Time
g	Gram	Mass
lbs	Pound	Weight (1lb $\approx$ 0,4536 kg)
C	Celsius	Temperature
m	Meter	Distance
ft	Foot	Distance (1ft $\triangleq$ 0,3048 m)
" or in	Inch	Distance (1" $\triangleq$ 0,0254 m)
V	Volt	Electrical Voltage
A	Ampere	Electrical Current
W	Watt	Power
Pa	Pascal	Pressure
dBA	Decibel A-weighting	Sound Level
Hz	Hertz	Frequency
rpm or $\text{min}^{-1}$	Revolutions per Minute	Rotational Speed (1 $\text{min}^{-1}$ $\triangleq$ 0,01667 Hertz)
N	Newton	Force
Nm	Newton Metre	Torque

## Chapter 1: Introduction

Kaplock B.V. is a new company whose production is based on 3D prototyping. Due to their rapid prototyping they perform a high number of tests by printing many iterations of each component of their Kaplock. The prototyping stage is very extensive, so once they achieve their final design for each component there is much waste produced. This waste comes from prints that failed due to 3D printing being a new technology, support structures from the prints, and the waste also comes from the early prototypes that will no longer be used.

Which, as is logical in 3D prototyping, an error test method, the company has high levels of plastic consumption that has to be reduced because plastic consumption has a high economic impact, particularly, when we consider that Kaplock B.V. is a start-up.

To estimate the economic impact of PLA consumption, on the total cost of printing any model, an example will be used.

Assume a 3D impression of a model of good quality in which 100 grams of PLA are to be used, and whose estimated duration is five hours. In these five hours are include both the support structures and the start layer printing. The 3D printer model considered for the example is the one that the company usually uses, the Prusa Mk2 i3. This is a printer destined for domestic use and also in small companies, very accessible and easy to use. The costs are broken down as follows:

- **Filament cost:** It will be considered a good quality filament of the brand, Materials To Build 3D, with a diameter of 1.75 mm. It will cost a total of € 3.42, which means 52.48% of the cost of printing.
- **Devaluation of the printer:** Considering that the value of the printers that Kaplock B.V. has, € 999, and assuming that they will print two hours a day for five years of useful life, makes a total of 3650 printing hours. Taking all this into account, the cost will be € 2.16, which represents 33.14% of the total.
- **Consumable items:** Consider tape as adhesive, alcohol spray, blades ... etc. These item costs are minimal and very difficult to calculate, so it will be considered that they only represent the small sum of €0.10. This is a 1.53% of the total.
- **Electricity:** As for the cost of electricity, this is very low in comparison with the rest of the variables, practically negligible. In this example it will be considered a consumption of € 0.1, which represents 0.6%.

- **Reparations and Updates:** In this example an extra 20% is considered on the purchase price of the printer, which, applied to the useful life of this printer, means € 0.21 in five hours of printing and represents 3.15%.
- **Error price:** It is going to be considered a margin of error of 10% printing, therefore applied to the total cost that has been obtained so far, will mean € 0.59, which is a 9.09%.

This cost breakdown shows the importance of the PLA recycler because over half of the cost of 3D printing comes from the filament. This large cost justifies the need to implement a corrective measure. Implementing this machine and recycling the 3D models into new PLA filament will help to reduce the cost of 3D printing. A reduction of cost will make 3D printing more available to everyone, so more people may begin to use 3D printing methods. This increase in popularity has the opportunity to have many benefits. Since more people will be exposed to the capabilities of 3D printing, this influx of new users may increase the applications in which 3D printers are used and increase the products produced from 3D printing.



## Chapter 2: Kaplock B.V.

Kaplock is a new start-up company which is trying to address the problem of jacket theft in the Netherlands. The company is based in Breda, established on November 24<sup>th</sup> 2017, and the office is located in an affordable office space for start-ups called the Incubator. Willem Pennings and Dhargyal-Sebastiaan van Oorschot run the company and are the brains behind the product. Their innovative product, The Kaplock, insures that every jacket is safe for the small price of 1 euro. Figures 3 and 4, below, are examples of The Kaplock.

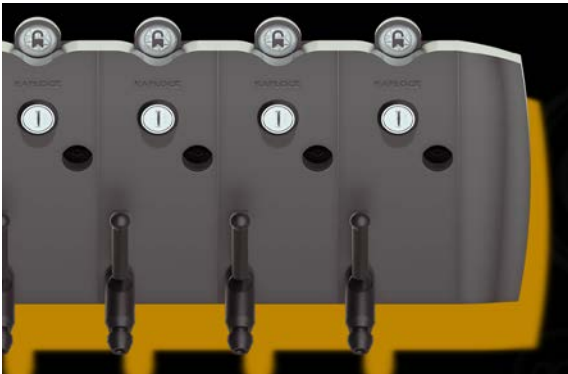


Figure 4. Standard 3D Printed Kaplock



Figure 3. Custom Jack Daniel's Kaplock

The product uses a steel cable and a locking mechanism to protect the client's jacket and allows safe storing without the use of a coat or locker room. This allows venues to store jackets without having to hire a coat check and eliminates the space that lockers occupy. The way it works is simple, the consumer inserts a 1 Euro coin or 1 Kaplock coin into the device which opens the Kaplock. Once it is opened the customer pulls the steel cable to a desired amount and pulls it through one sleeve of their jacket. The cable is then pressed back into the Kaplock and the coat is hung on the hook. The jacket is now secure, and the customer can take the key out. When they return they only need to do is put the key back in and the mechanism will release their jacket.

## Chapter 3: Project Description

The task carried out by the Kaplock team was the creation of a device that can recycle all the PLA that is wasted due to 3D prints. To carry out this task the project group decided to create a PLA recycler, which consisted of three main components: a crusher, an extruder and a coiler. The goal of this recycler was to grind the PLA, melt it into liquid, extrude it with the required diameter, and then coil it onto a filament spool so that it can be used again.

The project plan which includes project stakeholders, goals, program of requirements, plan of approach, schedule, time management and risk assessment can be found in Appendix 2.

### Chapter 3.1 Project Boundaries and Scope

The boundaries of the project were mainly established from the company participating in the EPS program, Kaplock B.V. The project's boundaries include the scope, the goals, and the constraints given to the project team. These constraints consist of; the time frame to work on the project, the requirements desired of the final product, the means to achieve the requirements, and the filament quality produced the final product. The company chose for Team D to develop the PLA Recycler due to the excess amount of PLA that Kaplock B.V. had acquired over time.

Once Team D completed the study and research stage of the project it was determined that the initial project scope would not be attainable. The project group made the decision to request a project scope change from the university tutor as well as the company due to the lack of resources available. The initial project scope was to build a machine that would be readily available to the public, compact, and require minimal user input. The product was sought to be as independent and accessible as possible, as well as marketable.

Team D decided that the main goal of the product would be to recycle the PLA that Kaplock B.V. had from their previous projects and not focus on creating a device to be marketed to the public. This simplified the project for Team D and made the project more feasible given the constraints. The product would not be meant to be marketable, but Team D would create in the report instructions and recommendations that a user could follow to create their own PLA recycler that would fulfil the original project scope. The project scope can be found in Appendix 2.

## Chapter 3.2: Project Stakeholders

The project completed by Team D had several different groups of stakeholders including the workers of Kaplock B.V., the members of Team D, and the staff of Avans University of Applied Science. Kaplock provided the project and the funding. They were also the direct benefactor of the project and the final device produced by Team D. The stakeholders at Avans University were responsible for finding Team D a project to work on during the EPS semester and provided the students with supplementary classes to ensure they were fully prepared for the four-month project.

## Chapter 3.3: Project Goals

The project team gathered with the company tutors and the university defined the following targets:

- To build a functional device that allows the PLA to be recycled, extruding a 1.75 mm diameter filament (standard measurement used in Kaplock B.V.)
- To provide a detailed report in which a marketable and autonomous product could be achieved.
- To provide list of components necessary for manufacturing, including drawings and a bill of materials.
- To provide advice and recommendations to carry out the manufacturing of future versions and prototypes.

## Chapter 3.4: Project Management Methods

To adapt to Kaplock's operating principles Team D agreed to use the project management method "Scrum". Scrum is an agile method which is commonly used for product development and multiple iterations. The scrum team consists of three roles, a product owner, a development team, and a scrum master. The product owner was Kaplock B.V. as they chose the project and set the requirements for the final outcome. Viktor, chosen as the scrum master, had the goal of protecting the scrum process and securing an information flow between the departments. The third role, the development team, was filled by all members of Team D. Their purpose was to fulfil "sprints", which is an assignment or task that is broken into simple steps to be completed in a short amount of time.

Every two weeks there was a meeting in order to look back on the completed sprints and plan the next sprints. Every two weeks the team also met with the university tutor in order to share the progress and get feedback. Additionally, daily stand-ups were help in order for each member of the development team to provide an update on their work, share which sprints they would take, and share the next steps in their work. These plans were underpinned by individual fillings of daily timetables. A Gantt Chart and a Work Breakdown Structure were developed in the planning phase at the beginning of the project and updated on a regular basis to provide an overview and orientation for all members.

## Chapter 4: Process of Work

At the beginning of the project Kaplock team decided to set all the phases the project would go through. The project was divided in the following stages:

- Preliminary
- Research phase
- Testing phase
- Prototyping phase
- Final design
- Final product manufacturing phase
- Final Deliverables

Once the division of tasks and phases of the project were completed and organized, the project group based their style of work on Scrum. This was important due to the lack of visibility the team had regarding this project. By using a project management method with many iterations, the team would be able to adapt as they learned and as problems emerged. Each task carried out during all the phases involved a Sprint to guide the team towards the final objective.

Apart from the task distribution previously mentioned and due to the fact that each member of the project group comes from a different background, the workload was divided between the following groups:

- Mechanical Engineers: David Adamovicz and Pablo Blanco
- Electrical Engineer: Viktor Dell
- Product Design: Dan Kordys

The mentioned phases are extracted from the Project Plan, found in Appendix 2, while the actual phases of the project were determined to be:

- Research
- Testing
- Prototyping
- Design development
- Outcome

### Chapter 4.1: Research

In order for Team D to become more familiar with the concepts that contribute to a shredder and recycler machine, extensive research was done. At the start of the semester research was done regarding 3D filament recyclers that were already available commercially. Looking at devices such as the 3devo recycler and the Filastruder, the team was able to gather inspiration for the design, technology necessary for the recycler, and understand some of the specifications in the industry. Research on other recyclers helped the team understand the market, the target demographic, common characteristics between different machines, and the

differences between each machine. The mechanical engineers looked into non-conventional ways

Due to a lack of established products in the plastic recycler market, the designer focused his initial research on the 3d Printer market, in order to get an idea of the design trends and innovation that is currently available to the consumer. While researching 3D printers the designer updated the engineers on his findings and vice versa. This allowed the design development process to flow better and helped the team to avoid confusion with the progress as well as being able to implement new ideas faster and more efficiently.

Once sufficient research was gathered about the 3D printer market the designer could start the design development stage through conceptualising the ideas he obtained from the research. The rest of the research done by the designer was topical to the development at the time. Things such as the different styles of printers and their size were researched, and key components that needed to be placed in the final product. This gave the team an idea of the scale the product would have as well as which parts should be manufactured/outsourced first. The majority of the research done by the designer wasn't planned and was done in tandem with the design development, due to the nature of the design process.

## Chapter 4.2: Testing

The testing phase was carried out throughout the entire project due to the nature of the project. Team D constantly had sprints that required more prototyping or testing, which resulted in a long testing phase.

### Chapter 4.2.1: Filament Testing

To test the impact of different conditions on the diameter of the filament, a filament width sensor was used. The main component consisted of a TSL1401CL module, which contains 128 photoreactive pixels. This is mounted in a 3D-printed case with a hole on top side, so that the filament will block light from reaching the pixels in the middle of the module. Larger filament would block more pixels from seeing light, which would cause an increase in the voltage output. This voltage was then converted into millimetres to determine the diameter of the filament. After testing with different temperatures Team D discovered the optimum operating temperature to be 195 degrees Celsius. Figure 5 shows the filament diameter over time, while Figure 6 shows the nominal distribution of the size.

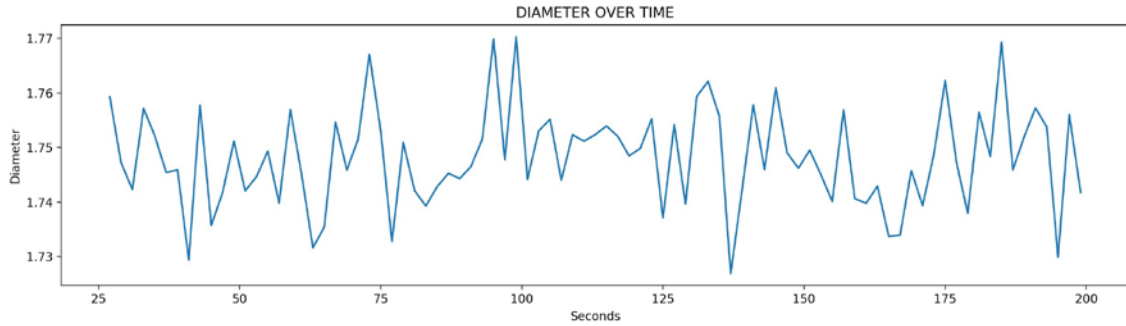


Figure 5. Filament Diameter Over Time

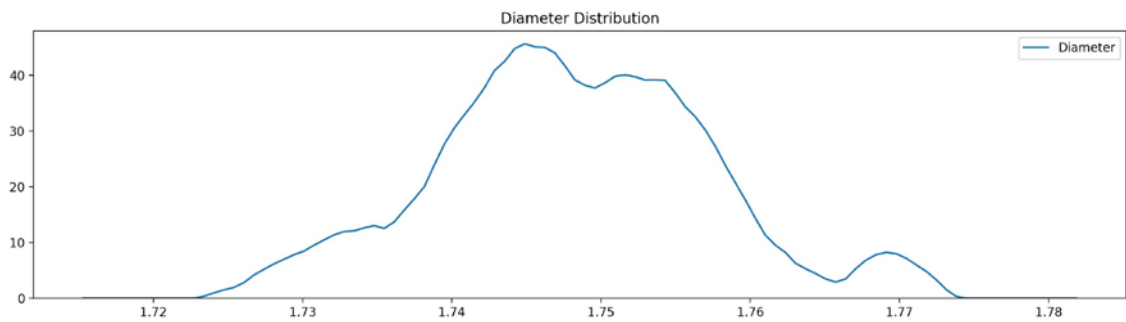


Figure 6. Nominal Distribution of Filament Diameter

## Chapter 4.2.2: Crusher Testing

In the first month of the project, during the research stage, the project team went to the workshop at Avans to inquire and test one of the crushers that was manufactured by students in the metalworks class. Team D took measurements of the crusher case, investigated how the motor was coupled to the shredder box, and the motors characteristics were noted.

From this first test the following conclusions were obtained:

1. The motor used in the workshop, despite being more powerful than the one available in Kaplock, jammed on several occasions, due to the strength of certain PLA structures. This led Team D to consider buying a more powerful motor or using other crushing techniques, which will be presented later.
2. The particle size was greater than what Team D desired. After completing the test, the team checked the average size of the crushed PLA and found two main problems regarding the size. The average size of the PLA grain was too large which would lead to insufficient melting during the extrusion process. This could potentially lead to the extrusion nozzle becoming clogged. The second problem was that the grain size varied considerably. This could lead to irregular melting during the extrusion process which would then produce a filament with irregular characteristics.

3. If obtaining a larger motor would not be possible, then alternative methods must be used to reduce the size of the PLA parts. After examining the technical specifications of each motor, it could be seen that the motor used in Avans had a power of 3 KW, while the company's motor had a power of 0.8 KW. This led the project team to consider the option of using a two-motor system consisting of one high-speed and one low-speed. Appendix 3 shows the motor characteristics of the motors tested.

### Chapter 4.2.3: Angle Grinder Testing

After having performed the engine test, Team D made the decision to buy an angle grinder with a high-speed built-in engine, with the idea of building a two-stage shredder. The concept was to have two sets of blades, one turning at a high speed to cut through the plastic and another set of blades rotating at a low speed that would push the PLA parts against the high-speed blades. In theory this system would require much less torque than the standard crusher style shredder, and thus reduce the size of the motor needed.

The problem found in this test was the angle grinder's high speed caused excessive friction between the blade. This caused the PLA to melt and then burn. If the burned PLA would be extruded into new filament, there would be changes in the properties of the filament. The changes made in PLA properties due to burning can be found in Appendix 4.

### Chapter 4.2.4: PID Tuning

One of the key aspects of the PLA recycler was the extruder. This component was responsible for melting the PLA and extruding the plastic into new filament with the correct diameter. The melted plastic was pushed through a nozzle at the end of the heating unit by a snail screw. The diameter of the filament was influenced by the speed of the worm screw, the size of the nozzle, and the temperature of the extruder. The speed of the snail screw and the size of the nozzle was designed to remain constant so only the temperature could be changed in order to alter the diameter of the filament. With high temperatures, the viscosity of the liquid plastic would increase, resulting in a smaller filament. In contrast, as the temperature decreased, the viscosity would decrease, and the filament size would increase.

The temperature of the extruder would not remain constant due to the different grain sizes of the crushed PLA, errors in the heating coil, and other external factors such as humidity and ambient temperature. In order to control the temperature, a PID controller was used. Many tests were done with different gain values to find the most stable PID response and to reach the temperature set point the fastest. By creating a quick and stable PID response the user would be able to use the PLA recycler quickly after starting it, have a consistent filament diameter, not risk burning filament, and not risk having the work screw become stuck due to the solidifying plastic.

## Chapter 4.2.5: Blade Testing

To investigate how to cut the plastic parts with the angle grinder Team D bought a pair of blades specific for concrete and steel. These blades led to the plastic burning and the consequences of burning the plastic were mentioned before. The test failed due to the large amount of friction between the blade and the plastic, as well as the blades not evacuating the heat properly. The style of blade used in the angle grinder had a large surface area that came into contact with the plastic, which caused excessive heat. As mentioned before, the blades the team used were specific for steel and concrete, so they could not evacuate the heat as efficiently as plastic blades do. Moreover, the disc blades had a continuous edge making the cool down process far more difficult and slower. For all these reasons the temperature of the cutting disk was too high, above 200 C (PLA fusion point), and consequently they burned the plastic.

After the first test, the project team decided to buy thinner blades designed specific for plastic. The mechanical engineers tested them, and it was discovered that the PLA was still burning. Once the blades had been examined it was concluded that the reason of this second failure was the lack of discontinuities in the edge of the blade. After this unsuccessful test the mechanical engineers asked for advice from ToolShop NL, a company with lots of experience in building and designing. Their recommendation was to buy a very specific sort of blade, suitable for high precision cutting, from the brand Amana Tool.



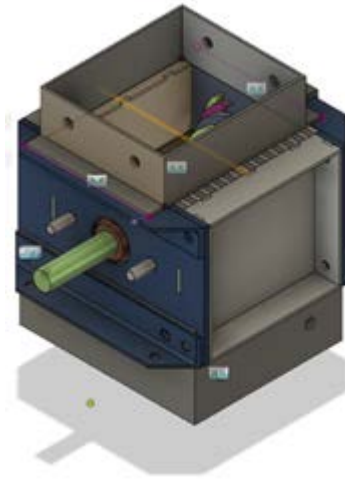
Figure 7. Amana Tool Blades Designed to Cut Plastic

The problem the team faced with this option was the expensive price these blades had, as the cost per blade was €105. Considering that 10-12 blades would be required for the crusher, this option would not be feasible.

## Chapter 4.2.6: Motor Adapter Testing

One of the most important components tested by Team D was the connector that coupled the rotation movement of the motor output to the input shaft of the crusher. The purpose of this component was to fit around the input shaft of the crusher and to fit inside the motor's output channel. This piece needed to be strong due to the torsion it would experience throughout the crushing process.



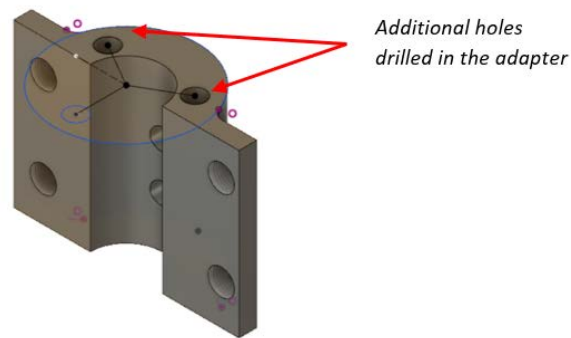


*Figure 8. Shredder Box With Green Input Shaft to Show The Location of The Connector*

The first of the prototypes manufactured by the mechanical engineers was made of PLA and consisted of two pieces which would be connected using bolts. The problem when testing this connector was that the torsion forces transmitted through the metal shafts were too large to be supported by plastic. The adaptor was 3D printed with layers oriented to have a high resistance longitudinally, but in turn would have lower resistance transversely. When applying torsion, which has both longitudinal and transverse force components, the PLA fractured at a stress concentration point.

After carrying out the first test and observing that the connector failed in the most vulnerable area (a point where there was a 90-degree angle), the team of mechanical engineers made the decision to redesign the piece trying to expand the section at that point and reduce the stress concentration.

Once the piece was printed and the test repeated, it was observed how the piece failed again in the same section and in the same way. after examining the fracture layer, it could be observed how it had been broken again in the same way, by the transversal direction. Therefore, the decision was made to carry out repairs in the crusher, which would reduce the friction between the blades and the walls of the crusher box. So, the crusher was disassembled, and each component was sanded and the oxide it had on its surface was cleaned with special products. In addition to carrying out this measure, in order to ensure the strength of the adapter, the adapter was designed with two holes along the length of the adapter in order to insert two M8x80 screws. The theory behind this was that it would increase the resistance to failure due to torsion because the part would be stronger from the metal screws.



*Figure 9. Modified Connector to Increase Strength*

The new adapter was stronger than the previous two designs, since it was able to crush small sheets of PLA. Despite the success it was not enough to crush larger parts of PLA. Appendix 5 shows the failures of the adapters.

After the third failed test, the team of mechanical engineers decided to completely redesign the problematic piece. The changes that were applied were the following:

- Reduction of two components to a single component: In this way the assembly by bolts was eliminated] which eliminated the high stress due to only half of the adapter bearing the stress.
- Increase of the thickness of the assembly to the axis of the crusher: In order to provide a greater section and consequently a greater inertia, the circular section of the assembly was extended from 40 mm in diameter to 50 mm.
- Removing sharp edges: As it is explained in the Appendix 5, the sharp edges are high stress concentrators, so the mechanical engineers designed a gentle curve between the two different sections in order to distribute the stress through the part.



*Figure 10. Final Connector Designed*

After designing and printing the new connector, it was tested again and in this case the test was successful. Different sizes of PLA were tested, and the desired result was obtained in all of them.

Finally, after having found the optimal design and following the advice of the company, the team of mechanical engineers decided to manufacture the latest version of the steel connector. This was carried out in the workshop of Avans (Den Bosch) with the collaboration of the staff there. The staff at Avans recommended to eliminate the curve between the two sections because it would be more difficult to manufacture and was not necessary due to the strength of the steel.



*Figure 11. Final Clutch manufactured in Avans' Workshop*

## Chapter 4.2.7: Filament Roll Counting

To prevent the user from needing to check the coiling status repeatedly to determine when the coil is full of filament, the system should on its own determine when a roll of filament is fully coiled. Implementing a sensor inside a roll was not possible since rolls are frequently changed by the user. Therefore, the coiling status had to be measured outside the roll. Due to its direct correlation with the amount of filament produced, the amount of revolutions of the coiling motor was counted internally by the Raspberry Pi, resulting in a program stop when a certain amount of revolutions is reached. This program stop was necessary or else the coil would continue to wind without having space for filament. There were three different methods tested for counting the revolutions of the coiler: a shaft encoder, a photocell sensor, and a stepper motor.

To use a shaft encoder a special sensor would need to be attached to the shaft of the motor to convert the angular position of the axle to a digital value. The sensor would need to be attached to the shaft because if it was attached to the other side of the filament roll the user would need to attach it themselves, and the project scope determined that the final product would require minimal user input. Using a shaft encoder is precise and inexpensive,

but it would take up a lot of space because it would require the axle of the motor to be larger and need to use more GPIO pins on the Raspberry Pi board.

A mounted photocell sensor was also an option investigated. This sensor would activate every time that the coiler completed a revolution by reading an irregularity on the roll. Since external filament rolls are used this also requires the user to attach an object to the roll every time a roll is changed, which would be too much user input.

The final option to count revolutions of the filament roll was a stepper motor. While a stepper does not have the ability to decrypt its angular position, it receives a command from the Raspberry Pi to move a given angle. As the Raspberry Pi tells the stepper to move, it keeps track of how much the stepper has moved over time. This counter represents the amount of full rotations the filament roll experiences. The stepper motor can be operated in half-step or full-step mode. Operating the motor in half-step mode ensures a smoother rotation than in full-step mode due to the decrease in step size. Despite a loss in torque of approximately 30% the motor is still capable of rotating the spool.

After evaluating all three options to count the filament roll rotations, Team D decided to pursue using a stepper motor due to its simplicity and effectiveness.

### Chapter 4.3: Prototyping

While Team D produced two main prototypes, each component inside the PLA recycler underwent several revisions. These prototypes were vital to the growth of the machine and to help each member visualize the changes of the PLA recycler. The first prototype, shown in Figure 12, is a visual representation of the PLA recycler presented at the midterm assessment. It was designed to show the audience the functions of the final product and what the team would strive to achieve by the end of this project. The second prototype was made to be functional and help the team investigate which parts needed to be altered and innovated for the final design of the product. With these prototypes created, the team was able to spot issues in the design and implement changes.



Figure 12. First Prototype

### 4.3.1: 3D Printing Issues

During the prototyping phase the project team mainly created models using 3D printers. Kaplock B.V. gave Team D access to their 3D printers, 14 Prusa i3 MK2s, and 2 Ultimaker 2s. Kaplock B.V. also gave access to the company's SLA printer but it was not used.

3D printing is a new concept and the technology is still progressing. It is common for prints to fail due to mishaps during the preparation of the models and during the prints. Parts can fail during printing due to their shapes, a lack of support, an unlevel bed, nozzle failures, sensor failures, debris on the bed, or the bed being bumped during a print. To fix these problems Team D began using a better 3D slicer software, ensured all printer beds were clean before printing, and routinely performed maintenance on the printers. Problems that impacted the printing are investigated below:

- Nozzle too close to the printing bed: This is a common issue that the project team experienced. It consists of an absence of filament flowing through the nozzle, despite having correctly loaded the PLA roll. In this case the melted filament does not have space to escape and is the reason why sometimes the print misses its first layers and does not stick once the filament does extrude. What the project team did to solve this problem was to adjust the Z axis of the 3D printer.
- Blocked Nozzle: Another quite common problem that the team faced was a blocked or clogged nozzle. In this case, a blockage of the PLA flow occurs, which means that the print fails due to no filament or fails due to poor filament being extruded. This problem was solved by heating the nozzle (in the case of PLA was heated to 200 degrees Celsius) and cleaning it with a brush.
- 3D printer missing the bed: A less common problem that the project team had also observed was the loss of spatial reference by the printer. This caused an erroneous impression, since sometimes the printer tried to print beyond the limits of the bed. This was from either a bad design or a problem with the software of the printer itself. In both cases the problem was solved by resetting the printer and recalibrating it.
- Not reaching temperature set point: A common problem for the printers was the bed temperature sensor falling off. This would result in the 3D printer not reading the actual temperature of the bed, so it would continue to heat the bed to reach the set point. If the sensor was slightly separated from the bed, the printer made start with the bed too hot. If the sensor was very far from the bed, the printer would never start due to the set point never being reached. This problem was quite common to encounter, and it was quite easy to overcome. Simply by looking at the sensor it was clear if it was touching the bed, or if it had separated. If it was separated, then the only repair necessary was to relocate or replace the temperature sensor responsible for reading the bed temperature.

- In addition to all this, less common problems had also been experienced, such as design errors that gave rise to complex support structures, which were unviable, or unevenness in the printing bed caused by mechanical reasons.

## Chapter 4.4: Product Development

The design development was carried out throughout the project and was background work to aid the visualisation of the outcome. It was also a tool which aided the team with innovation of the recycler. The process of design development worked in tandem with the researching phase. Once new research was carried out and useful information was obtained the designer proposed new ideas to the team. The team then discussed the ideas together and agreed upon which additions would be made to the design.

Although the design of the product appears not to change drastically between some of the phases, a lot of conceptual work was done by the designer. To reach an outcome that the team and the client could agree upon many different possibilities and features were discussed and evaluated. The development didn't only consist of sketches, but also mind maps and diagrams such as the fishbone where used to aid the thought process.

The entirety of the design development process is shown in Appendix 6. The remainder of Chapter 4 also gives an overview of some sketches from the design development process. This development process shows the progress of the project as well as the thought process of Team D.

### Chapter 4.4.1: Initial Designs

The initial designs were the very first design ideas that explored the shape of the product as well as some of the key features. For this project the designer was inspired by desktop 3D printers and CNC machines. The design process started with compiling different ideas the team had into a series of small sketches. Creating these sketches allowed the team to visualise the different designs and pick which features would work in the final product.

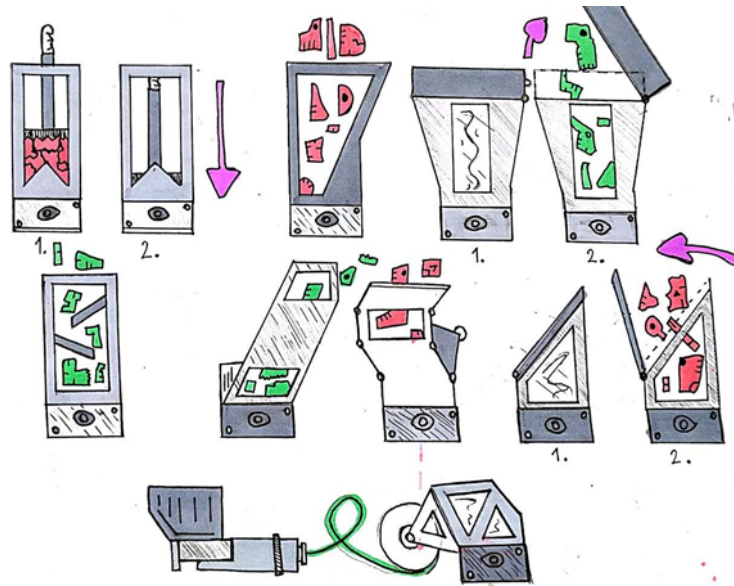


Figure 13. Initial Designs and Inspiration

The conceptual outline of the product started to form and so did the thoughts of the group. The shape, size, component list and many more things were discussed. Although some of the proposed ideas had a heavier impact on the general concept, the design was not finalized because limitations, innovative ideas, and client opinions were always impacting the design process. At all stages of the project the overall product was subject to change in order to achieve a better final outcome, although some stages had a bigger impact on the design.

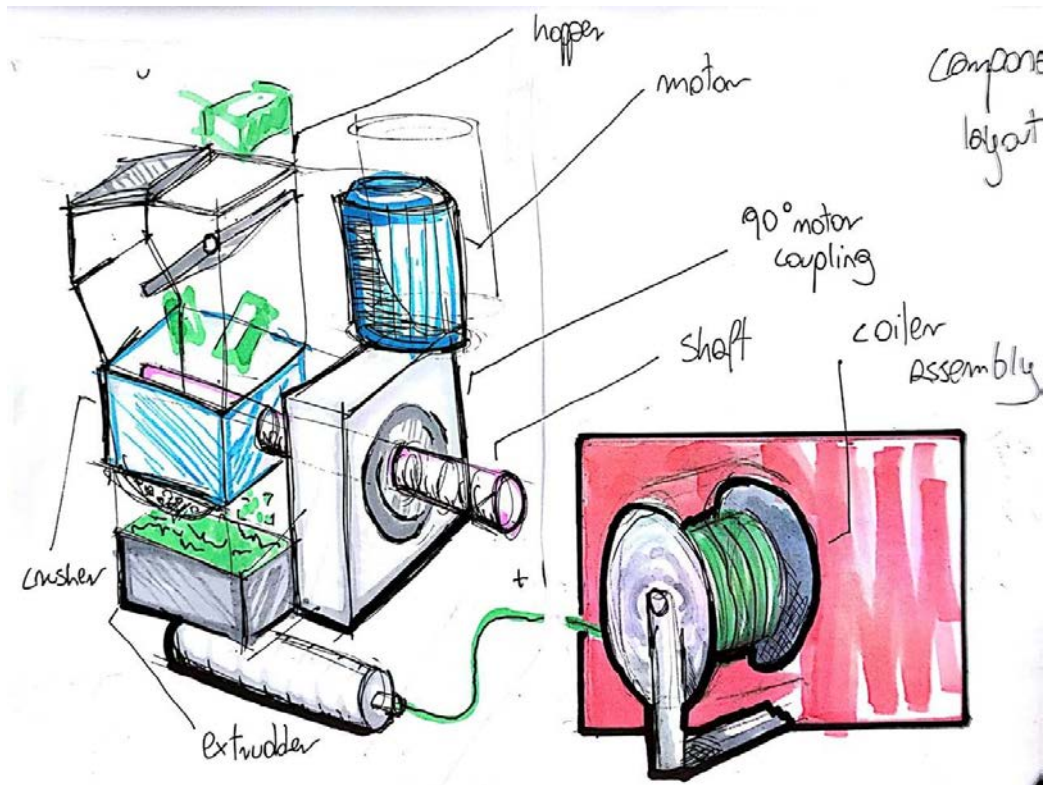


Figure 14. Further Development of the PLA Recycler

## Chapter 4.4.2: Design Development

The next stage, Design Development, focused on fine tuning and progressive a buildout of the product. Research of the initial theories and ideas was conducted by the team to see if their choices were feasible. Testing these theories as well as creating prototypes of components was a big part of the development, new ideas and theories emerged and some previous ones were rejected. The materials and basic measurements of the product started to emerge in the development as the team progressed.

Once the components list was finalised by the engineers the designer worked on the placement within the main frame of the product. Figure 14 is a sketch visualisation of all the components working together, drawn by the designer to help understand some of the limitations the design had. The sketch also gives insight on how the components can be better arranged to give the desktop machine a more compact look while saving on some of the material costs. Figure 15 is an example of how the product changed through the development impacted by the many variables mentioned before. In this case the frame had been reduced in size and the coiler re-arranged into a better position, the frame had also been swapped for a metal construction rather than a box which holds everything together.



As the development progressed the designer focused on small parts of the concept, further narrowing the list of unknown components and processes. Things like size of fasteners and the layout of the buttons as well as their sources are explored and agreed upon by the team.

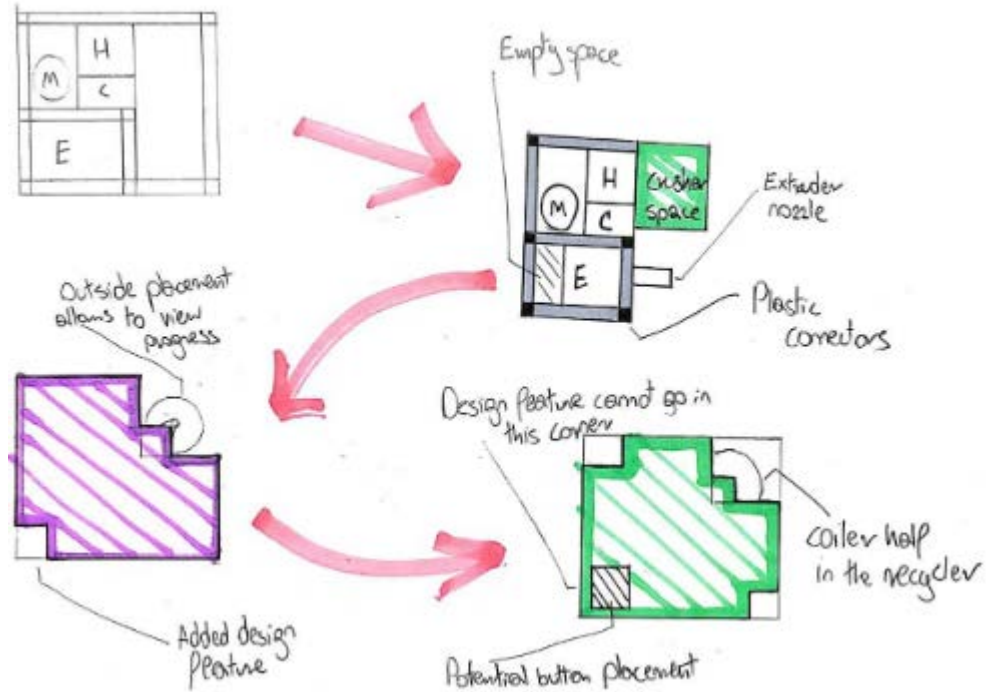


Figure 15. Frame Development

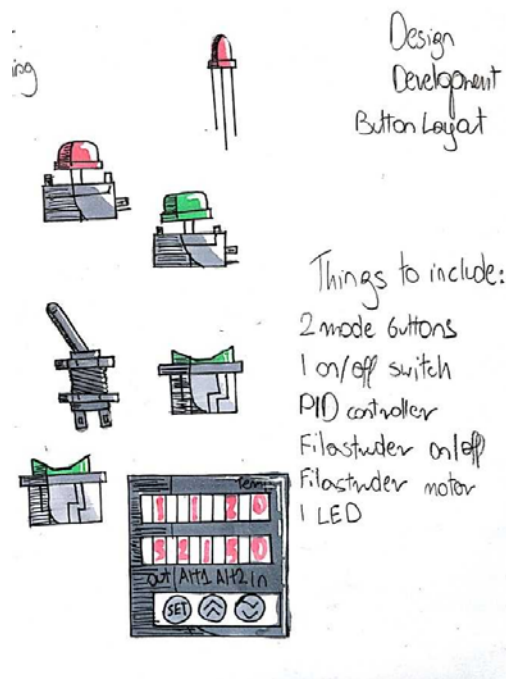


Figure 16. Switch Development

## Chapter 4.4.2: Final Design

In this stage the design was finalised by the team and all the details were reanalysed to make sure the components worked properly as well as to find any details about the design that might have been overlooked earlier in the process. Although the design was being finalised, some changes also occurred in this stage. However these changes were minor differences and not big drastic changes to the design. A final prototype of the full working machine was constructed in order to show the moving parts and potential exterior of the recycler. Usually in the industry the product is then signed off by the project manager and prepared for product.

## Chapter 4.5: Final Outcome

The shredder contains a motor to slowly turn the blades inside it with a high torque to crush the inserted parts. It is recommended to plug this motor separately if possible to prevent malfunctions of the system due to changes in power consumption. The motor is activated by a switch, which is connected directly to it, to reduce the danger in case plastic is stuck between the blades and stops the motor from turning. This situation could cause the motor to break, so the user must turn the motor off and remove the plastic manually.

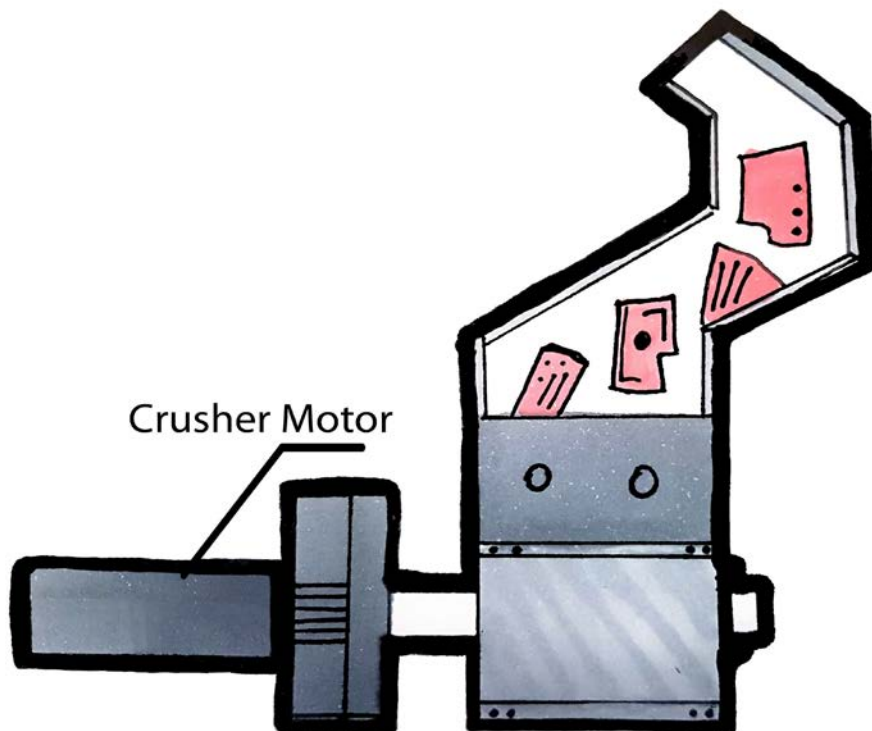


Figure 17. Crusher and Shredder Layout

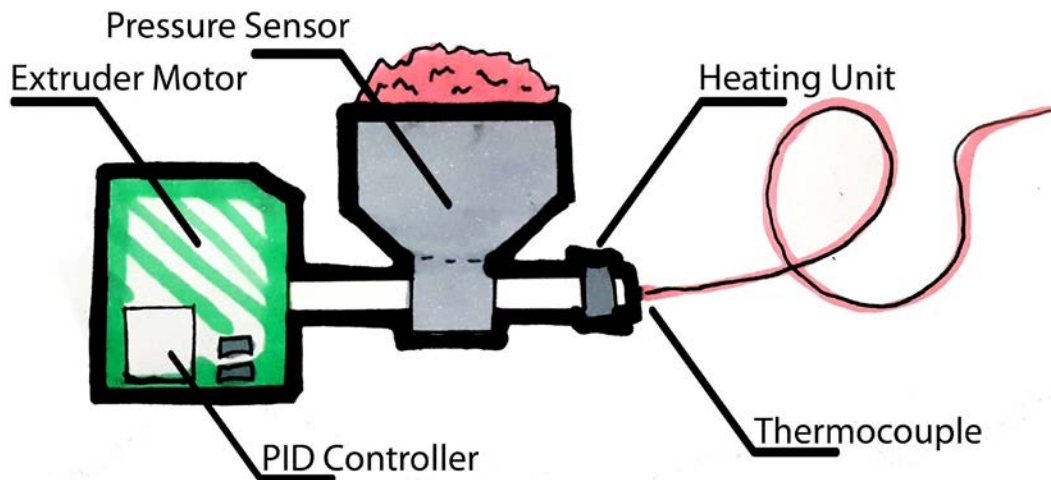


Figure 18. Extruder Layout

Within the extruder is the second motor, a simple 12V DC motor that is used to turn the screw within the pipe. It is powered with a consistent signal to maintain the speed of 8,18 revolutions per minute. The exactness of the speed is important due to its impact on the diameter of the extruded filament. Through the use of a relays the motor can only be in a closed circuit when crushed filament is detected by the object detection sensor TCRT5000. In case this loop is not closed, another inverted relay closes a second loop, that originates in the 5V provided by the Raspberry Pi, to lights up the LED to indicate, that new filament should be inserted by the user. The sensor is mounted on a wall of the adapter that connects the funnel under the crusher with the extruder. It is set to the lowest possible detection distance see the opposite wall on the shaft as an inserted object.

It was decided to use the “SESTOS PID Digital Temperature Controller” version D1S-2R to realize precise temperature control with almost no overshooting. The provided program on the Raspberry Pi contains a software-based PID controller as well, in case no external PID controller is available. The user has the possibility to change between these two options within the code. The setpoint of the PID controller is fixed at 195 degrees Celsius and the motor of the Filastruder may only be started when this temperature is reached to prevent the drill from pressing cold, hard PLA against the end of the extruder. The heat is measured by a K-type thermocouple which generates a voltage between its ends dependent on the input temperature. On the Sestos controller, the ends are attached at pin 3 and 4 on its backplate. When using the built-in PID controller, a thermocouple with an attached AD converter should be used, for example the MAX6675 Thermocouple. The data is transmitted via SPI to pin 7 (GPIO 4) of the Raspberry Pi.

The heating unit, a HBA-211220 nozzle heater, is connected to pin 7 of the PID or to a relay that is plugged to pin 22 of the Raspberry Pi. When using the Raspberry Pi as a Under the nozzle a fan is placed to increase the hardening of the filament.

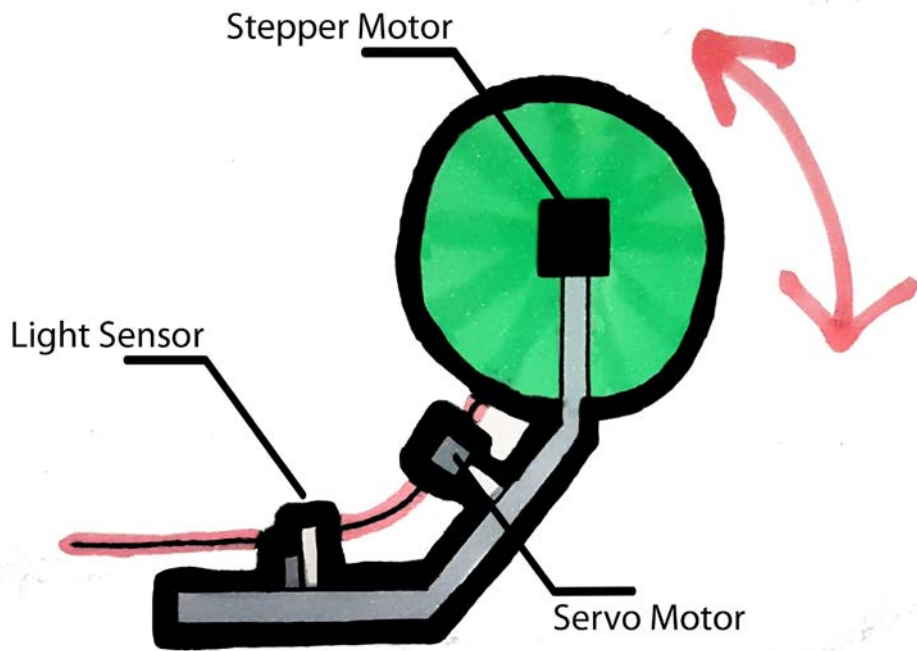


Figure 19. Coiler Layout

The automatization of the coiler is made possible through the use of two motors which react to a light sensor. The filament is hanging between the coil and the extruder. Due to further extraction and an increase of length, the hanging filament reaches the light sensor. Its activation lets the Raspberry Pi rotate both motors. The main motor, a NEMA 17 12V stepper motor, is connected to the computer via the L298N Bipolar Stepper motor driver plate, which uses an external supply of 12V to move the motor according to the 4 signal inputs of the Raspberry Pi. The motor is mounted to the coil attachment and rotates the coil for a certain fraction of a full turn to store the filament and prevent it from hanging any lower. Due to the use of this method stretching of the PLA is prevented, since the motor only turns when new filament is being produced.

The servo motor, a MG996R, is used to guide the filament to the spool and disperse it evenly across the width of the spool. It moves an extension arm with a hole in it, through which the filament is guided, repeatedly in a given angle. The range of the angle is inserted by the user in the program depending on the width of the used coil. Each full revolution of the coil the arm is moving 1,75mm to lay down a new row on the spool.

The main program runs three modes which can be switched by using two buttons at the input terminal of the device. The currently activated mode is indicated by the light of the LED next to the buttons.

<b>Stage 1:</b> LED color : magenta	Standby
<b>Stage 2:</b> LED color : red	PID controller activated
<b>Stage 3:</b> LED color : green       LED color : yellow	PID controller activated Extruder Motor activated Fan activated Coiling activated  PID controller activated                      Extruder Motor deactivated Fan deactivated Coiling deactivated

The complete program written in Python can be found in the Appendix 7.

## Chapter 5: Description of the Final Product

After having gone through all the stages mentioned in previous chapters and following the work process detailed in this report, team D, developing the project in the Kaplock B.V. company, has successfully completed the target of the project that was specified Appendix 2, after the change made in the Scope halfway through its development. In this chapter, a description will be made of the final product that the project team will deliver, organized as follows:

- Hopper
- Crusher
- Extruder
- Coiler

### Chapter 5.1: Hopper

The first part of the cycle that the recycler follows is the hopper through which the wrong 3D impressions that are intended to be recycled are introduced. The main requirements of this entrance hopper are:

- The entrance of the hopper must be wide enough to fit all the pieces of PLA of different sizes in it, including the full size of the star product of the company, the Kaplock.
- The hopper should not be excessively large, since as it has been said in the Scope of the project, it is about making a device as compact as possible, accessible to non-professional users, so that complex installations are not needed for use.
- For safety reasons, the nozzle must have a twisted shape with several direction changes in such a way that the user can not physically access the box of the crusher, in this way they are intended to reduce the risk of using the device.
- Finally, with purely aesthetic purpose, it is intended to make a partially transparent nozzle, using plexiglass, in order to create a device that is as aesthetic and attractive as possible.

Since the beginning of the project, the team of mechanical engineers have made numerous changes in the design of the hopper. In the research stage it could be observed in previous studies, that all the nozzles used in this type of devices had previously had a pyramidal shape, which could be risky for the user's integrity.



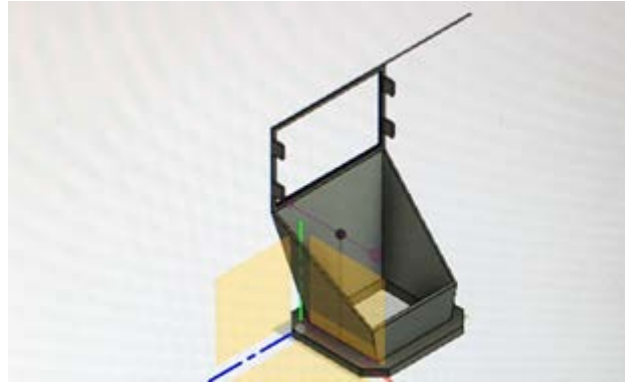
*Figure 20. Original Hopper Design*

During the test stage, the new design of the hopper, the one showed in the midterm assessment presentation was developed. In this second version, it could be already seen the effort that the mechanical and design members had done in order to make it as much visual and safe for the user as possible. In this version two type of materials were used, PLA and Plexiglas. What could be observed in the pieces of Plexiglas is that the cut had been made with a manual saw, so the quality and precision of the cut was very poor. In addition, the assemblies between the different components were carried out with fasteners, which was not desired by the company, therefore the mechanical engineers would work on its elimination in the future versions.



*Figure 21. Base for the Second Version Hopper*

After the midterm assessment presentation, the project team was recommended to make modifications in the hopper, since it was not wide enough, so the mechanical engineers team worked in parallel in two different designs, in which the dimension of the hopper was bigger.



*Figure 22. Concept for Final Hopper*

In this version the engineers tried to reduce the use of fasteners, which negatively affected the aesthetic aspect of the device, but they were not completely eliminated. It will be done in the final version. In this case there were again both PLA and Plexiglas components, but the use of fasteners had been avoided. Moreover, the Plexiglas was cut with laser cut methods, so the precision was notably improved.



*Figure 23. Final Hopper Design*

In this case, as can be seen in Figure 23, a system of slots is used in which the PLA can fit and in this way the use of fasteners is omitted. The Plexiglas drawing can be found in Appendix 8.



## Chapter 5.2: Crusher

The final crusher design used by Team D is a standard design with a rotating shaft that is connected to a set of blades. These blades push the PLA parts against a wall in order to increase the shear stress that the parts experience.

In the prototype presented for the midterm assessment, a non-functional crusher was used because the prototype was purely for visual understanding. The tests explained in Chapter 4.2 describe the two parts that make up the crusher prototype; a shredder and a granulator.

- Crusher: The crusher that was intended to be carried out, was a double shaft crusher with different rotation speeds. One of the axes would be connected to a low power motor, and conventional blades would be installed, as its purpose was only to collect and press the PLA pieces against the second axis of the crusher. The second set of blades would turn at high speed in order to cut the parts instead of crushing them.

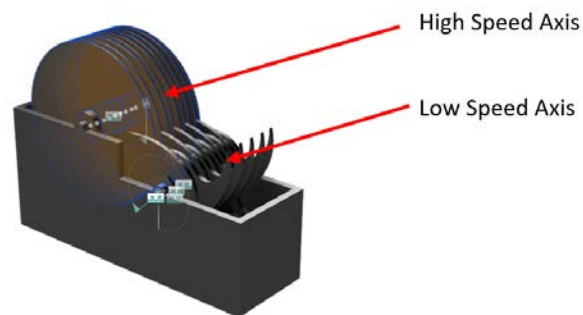


Figure 24. Crusher Prototype

- Granulator: After the first stage of crushing and after passing the plastic through a mesh, the size of the plastic was too large and irregular, therefore running the risk of obtaining a defective smelting in the extruder and consequently a worse property of the extruded PLA filament. So, the mechanical engineers made the decision to install a second stage of crushing in which the plastic flakes coming from the crusher were passed through a granulator that made them smaller and more uniform.



After having carried  
the mechanical engineers

out the necessary tests and  
have recognized the

Figure 25. Granulator Prototype

infeasibility of this crushing system, the team opted to carry out the construction of a conventional single-shaft shredder, as presented by Precious Plastic (see Appendix 9) in its latest version.

The objective of the team of mechanical engineers was to build in steel following the drawings provided by precious plastic in the workshop of Avans in Den Bosch. Due to a conflict of schedules this was not possible, so the team was provided with a shredder which had failures and that after fixing and practicing slight modifications, is the one used in the present project. See information about final crusher in Appendix 9 .

### Chapter 5.3: Extruder

Originally, Team D purchased a Filastruder to test with, develop a greater understanding of filament extruders, and ultimately to reverse engineer the device in order to produce a simpler version in the final product. As testing progressed, Team D understood that they had the capabilities to reproduce the product but decided to use the Filastruder in their final design. This came from the savings cost and the increased feasibility of the final product. Team D realized that if the PLA recycler was to be made for mass production, the extruder would need to be redesigned to save on costs and space. Since the project scope only required a working prototype, using the Filastruder in the final design would be acceptable.

Figure 26 shows the assembled Filastruder with the 3D printed hopper. The Filastruder has several main components consisting of a motor, PID controller, extrusion tube, screw, heating element, and thermocouple.



Figure 26. Assembled Filastruder

To use the Filastruder, the user must first turn on the device and allow the heating coil to warm the extrusion tube. The temperature setpoint, which will change based upon the plastic being extruded, must be set through the PID controller. The PID controller must also be

tuned in order to get a stable response. Once the temperature settles at the desired setpoint, the user may insert the plastic into the hopper and turn on the motor. As the motor turns the screw, the plastic is guided through the extrusion tube and begins to melt. As it reaches the end of the nozzle, the melted plastic passes through a filter and then a nozzle so it can be extruded at the desired diameter. As it exits the extruder a fan cools it in order to preserve the quality of the filament and not get pulled or twisted while it is malleable.

The only changes that Team D made to the Filastruder was to adapt the hopper to receive plastic directly from the shredder, connect the switches to the Raspberry PI, and add a thermometer to the nozzle to read the temperatures directly into the Raspberry PI.

## Chapter 5.4: Coiler

The coiler consists of two components, the coil itself and the coiling mechanism. The coil is a usual, standardized, PLA filament roll that is inserted into the PLA recycler by the user. Figure 27 shows a typical filament roll. In order to connect the filament roll to the coiling motor, a connector was 3D printed to be the same diameter as the hole through the center of the filament roll, 52mm. This is a standard measurement, but the width of the rolls is not standardized. Due to this, the user must input which size roll they are using during the setup. The coiling motor, onto which the roll is attached, is fixed to one of the upper edges of the cube shaped frame. To ensure a secure fastening for all roll sizes, the other side of the filament roll is held in place by a flexible strut.



Figure 27. Typical Filament Roll

The filament must be guided carefully from the extruder to the coiler in order to preserve the diameter of the filament. This is done by guiding the filament down a slide while simultaneously cooling it. Through this process the filament hardens and the characteristics of the filament are preserved. Each time a new roll is used the user must guide the filament by hand and attach it to the empty roll. Once attached the coiling mechanism functions automatically until a full roll is achieved, which is known by the number of turns the roll experiences.

As the filament moves between the gap of the extruder nozzle and the slide it sags due to its own weight. Between the slide and nozzle end there is a light sensor that is triggered when the filament sags too much. This light sensor sends a signal to the coiling motor to turn each time the light sensor is triggered, resulting in the filament being pulled and coiled. This constant feedback allows for the filament to continuously move down the slide.

The distribution of the filament across the coil is regulated by a servo motor which constantly moves back and forth. This allows the filament to be guided evenly and maximise the amount of filament that fits on each roll.

## Chapter 5.5: Recommendations

Once the project is finished, the project team presents a functional prototype, whose use is available to the company Kaplock B.V. and that it can be improved in the future in order to make it marketable following the recommendations that are mentioned below. Moreover, the team D presents this report, where are shown and detailed all the steps and all the necessary information to build and develop a relatively new way of recycling PLA.

- Install a motor with a higher power, since the one used in the prototype only represents 35% of the necessary power. Perhaps a brushless motor could be used to aid weight loss and improve the efficiency of the Recycler.
- Use a double crushing system with double axis, one high speed and one low. In addition, use a second granulation step in order to obtain a grain of PLA as fine as possible.
- Install in a hopper with an additional elbow, since despite having performed ergonomics tests and being difficult to access to the crusher, the user could still be hurt if they put their hand far enough into the hopper
- Install a sensor in the nozzle, so that it detects the amount of plastic that is in it, so if it is too full and the input speed of plastic is greater than the filament extrusion, it stops automatically.
- Install a visible and easily accessible safety switch. This would shut down the whole device in case of any malfunction or accident and prevent from self-destruction or harming the user.
- Add handles in strategic places on the frame in order to ease carrying of the machine and transport, these should fold into the framework to hide when not in use.

- Create an easy to use and simple instruction manual to clarify the correct use of the machine and maintenance of its respective parts
- Find a way to automatically guide the filament on an empty roll
- Make the machine lighter

## Chapter 6: Final Product

The final product consists of the four main components mentioned above, the hopper, crusher extruder and coiler. They are arranged in a way that ensures maximum efficiency while extruding plastic in terms of space and weight distribution. These components are attached to a framework for support, which in turn is encased in an exterior frame, the design was agreed by the team and can be clad with a range of different materials. The frame is made out of 20mm square aluminium bar, used to save on weight and connected via rigid plastic connectors to ensure structural integrity of the Recycler. It is turned on by plugging in the two individual power sources, a safety feature for the crusher component. By using two buttons the user switches between standby mode, warm-up mode and the fully automated recycling process. This process is only interrupted when either a full roll is generated or the sensor above the extruder detects a lack of PLA replenishment coming out of the crusher.

Once the electrical components are switched on and heated up sufficiently the user can begin to place the plastic in the hopper and begin the crushing process. The single axle crusher crushes the plastic into desired size and it falls through the grated sheet. If the plastic is too big the crusher picks it back up and crushes it once more. The granulated plastic falls into the internal hopper of the extruder and begins to spiral to the end where a heating element melts it into filament. The desired size of filament is decided by the temperature set by the PID controller. Freshly melted plastic is extruded out of the nozzle at the end and picked up by the light sensor as it sags. The user then takes the filament and attaches it to the coiler system, which is the only action required to be performed by the user except for switching between the different modes in the program. As the coiler coils the fresh filament, it controls the rotation and distributes the plastic evenly on the spool. The program automatically stops all processes when a full roll is achieved.

## Chapter 7: Conclusion

Team D was satisfied with the outcome of the final result, which satisfied the project scope. The members managed to meet the requirements of Kaplock B.V. by providing a product that was able to recycle the gathered PLA waste and make reusing future prints possible. The recycler was appealing due to the ease of use and minimal user input it required. There were only critical steps that needed to be executed by the user to ensure proper functionality of the device. In comparison to other available products serving the problem of recycling PLA, the recycler combined all three parts of crushing, extruding and coiling the plastic in one device and therefore in one continuous process.

Furthermore, a suitable use for the redundant motor available at the company was found by implementing it in the final outcome. Due to its low power, big chunks of PLA had to be bruised manually before being inserted into the machine, but Kaplock B.V. had adequate possibilities to do so.

Team D not only created a functional product but also delivered a complete documentation of its version of the invention, which can be improved in further steps. In case the project outcome would be used in a broader application area, outside the internal use at Kaplock B.V., an upgradeable framework is provided. A more powerful motor or other different parts can easily be added or replaced. Kaplock's employees have the possibility of further developing the recycler and therefore expanding its usage to solve the same problem at other companies and households.

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## Chapter 9: Appendixes

### FUSION 360 SOFTWARE

In this appendix all the information about the software the team has used is provided.

Fusion 360 is 3D CAD reinvented to become the next generation Product Innovation Platform incorporating CAD/CAM/CAE tool for collaborative product development.

Autodesk Fusion 360 is a fundamental departure from our current desktop bound CAD software, so let's have a deeper dive and get a high-level overview of what really sets it apart from the competition, why the platform is such a compelling offering and how it helps ends users and businesses meet the requirements, challenges and technological changes facing the design and manufacturing sectors.

#### **It's Integrated.**

Fusion contains tools to support the entire Design to Manufacture process within one CAD package.

Solid, Surface, T-Spline and Mesh geometry is supported. Drawing, Rendering and 3D-Printed output is available for design validation, documentation and prototyping. Within the same CAD package, Simulation and shape optimisation tools help us to check and validate our design, while integrated CAM allows us to manufacture the final parts.

#### **It's Connected.**

Fusion 360 runs on Windows, Mac and in your web browser so, it's not tied down to a specific operating system. The licence is tied to your Autodesk login, not the device you are currently using. The software's integrated document management system backs up all your working files to your Fusion 360 Team account making it easy for you to work from wherever you need to be.

The platform uses the power of the cloud to hand off compute intensive tasks such as rendering and FEA studies, freeing you up from having to sit at a dedicated CAD station.

#### **It's Accessible.**

It's a collaborative platform meaning you, your colleagues and your customers can access your files from any web connected device which can help to shorten design lifecycles and accelerate time to market. Viewing and mark-up tools are built in to the Fusion 360 Team document management platform. Asking for a customer review of your design is as simple as sending a web-link.

#### **A Variety of CAD Tools**

CAD, CAM, FEA and documentation are all built on the same platform, and integrated into the same CAD tool. This makes it easier to move your project through the various design phases out to presentation graphics without the overhead of having to learn disparate software packages.

### **Multiple Operating Platforms**

Fusion 360 can run on multiple operating platform such as Windows, Mac or in your web browser. There are F360 Apps for your iPhone and Android device so you simply choose what platform is best for depending on your preference or even your location.

### **CAD and PDM**

Data management is built into Fusion 360. No need to maintain your own database or server, no check-in or check-out.

Permission control, version and revision tracking, linked documents, comments, review and mark-up are all managed seamlessly and coordinated with Fusion 360 team.

### **Local and Cloud Resources**

The platform is an incredible hybrid between your local device and the cloud. Because Fusion can run on your PC or Mac, it will work even when you don't have an internet connection! When connected to the internet, Fusion has the incredible ability to pass off compute intensive tasks to the cloud to get the best out of your local hardware, and the scalable compute power of the cloud.

### **Concept design and 3D Modelling**

Autodesk Fusion 360 brings true 'Top-down' design to your workflow, with a single model environment in which all unique parts and assemblies can be created. Existing library files can be linked into your current design, allowing for 'change it here – change it everywhere' control of your standard parts.

It incorporates both direct and parametric modelling, allowing you to start with an existing design from any other CAD system, or create your own designs from scratch.

### **Prototyping and Fabrication**

Prepare your designs for 3D printing as a prototype or as a final part within Fusion 360's integrated 3D print preparation environment.

Once the final design is agreed, programme your part for 2, 2.5 or 3 axis CAM directly inside F360 and write out your post for any one of the many supported NC code post processors.

Traditional drawings have not been left out and can be created directly inside the platform.

3D Print models, CAM paths and Drawings are all directly linked to your 3D CAD model. When your model updates – everything else will too! Late design changes need not be a problem inside Fusion 360's integrated Product Innovation Environment.

### **Integrated Simulation**

The closer you can get your 3D CAD model to real life, the more information can be generated for Simulation and verification of your design. Minimise the number of physical prototypes you need to make, reduce costs and reduce time to market.

Fusion 360 includes integrated Assembly modelling, Motion studies, Rendering and FEA tools to help you analyse your design before you make it. Generate Static stress, Modal Frequencies,

Thermal, Thermal Stress, and Structural Buckling, Non linear Stress, Event simulation and Shape optimisation studies for a fraction of the price of dedicated simulation software.

**Document management and collaboration**

Document management is seamlessly built in to the platform. Files are automatically backed up to the cloud. Every save creates a new version for a full audit trail. All files are permission controlled and tracked within your project, so you can re-name and re-structure your files as you see fit at any time.

All files uploaded to the platform are available to your project team via the Fusion 360 document management web service, which includes commenting, mark up and live review of your designs. Whether you are sharing ideas with a no-CAD user in the same office, colleagues around the world or your customers, you have the tools you need built into the platform.

## Appendix 2: PROJECT PLAN

### Project Stakeholders

Project internal stakeholders include the project team, Avans University of Applied Sciences and internal customers of Kaplock B.V.

The tutor from Avans, Adriana Quintero Ramírez, has been interested in the project by holding meetings twice per month or even more, and supporting the team by doing a weekly blog in order to follow the process closer helping the team in times of difficulty. The project team will also work to keep EPS Coordinator Frans van Seggelen, who has also supported the project by giving advice and assisting to the meetings, satisfied with project work and results.

The foremost internal stakeholder is the project team which is formed by Viktor Dell, Dan Kordys, David Adamovicz and Pablo Blanco. All team members have invested time and effort in relation to the complexity of the project.

The team chose this project due to the creativity and flexibility that it offered, and what is more, because of the possibility of working in a start up where the whole process of create, develop and launch a product can be easily followed. The internal clients are the owners and employees of the company Kaplock B.V. that have invested time and interest and money on the project.

### Project Goals

The project team gathered with the company tutors and the University defined the following targets:

- To build a functional device that allows the PLA to be recycled, extruding a 1.75 mm diameter filament (standard measurement used in Kaplock B.V.)
- To provide a detailed report in which a marketable and autonomous product can be achieved.
- To provide list of components necessary for manufacturing, including drawings and cost list.
- To provide advice, and recommendations to carry out the manufacture of future versions and prototypes.

### Scope

The Scope of the project is to develop a functional prototype, but not marketable, besides creating a report in which all the steps and instructions to be followed are detailed so that any user can build and use an autonomous and independent PLA recycler ready to be launched in the market.

### Project Boundaries

The boundaries of the project group are the company participating in the EPS, Kaplock B.V. The reason why the team develops the recycler is the necessity that the company has. Kaplock B.V is the project owner.

### Plan of Approach

The plan of approach changed during the project because the scope changed. The final approach is distributed in different parts (see chapter 4 process of work). The documents of the plan approach can be seen below:

## Schedule/Time Management

### Team Roles

The project team split their tasks for each team member according to their background of study and the results obtained in the Belbin Questionnaire that was carried out in Project Management. In addition, the tasks were divided according to the personal potential of each team member which can be seen on Table 1.

<b>Team Member and Background</b>	<b>Role</b>	<b>Characteristics</b>
Pablo Blanco Espeso <i>(Mechanical Engineer)</i>	Team member	Shaper, Coordinator, Implementer
Viktor Dell <i>(Industrial Engineer)</i>	Scrum master	Monitor, Finisher
Dan Kordys <i>(Product Designer)</i>	Team member	Resource investigator
David Adamovicz <i>(Mechanical Engineer)</i>	Team member	Shaper, implementer, finisher

## Risk assessment

The project group created a risk assessment for the energy management system. The group concluded that there are six major risks. It can be found in the risk-impact matrix Table 2.

Likelihood	Consequences				
	Insignificant	Minor	Moderate	Major	Catastrophic
A (almost certain)					
B (likely)	4	6	1		
C (possible)					
D (unlikely)	3			2	5
E (rare)					

1. Lack of communication between workers and managers
2. Lack of commitment
3. Illness of a person with many responsibilities
4. New tools aren't used properly
5. The management doesn't support the project until the end
6. Lack of organisation of documentation

HAZARD	RISK	CONTROL MEASURES	EMERGENCY ACTION
Lack of communication between workers and managers	<ul style="list-style-type: none"> <li>-the work is not done efficiently:</li> <li>-the work is done twice</li> <li>-tension between workers</li> <li>-the solutions take longer to be carried out</li> <li>-the project may lose its direction and may stagnate</li> </ul>	<ul style="list-style-type: none"> <li>-incorporate energy target to the KPI</li> <li>-Weekly meetings about the status of the process between the energy management team.</li> <li>-share information and results ALWAYS</li> </ul>	<ul style="list-style-type: none"> <li>-make the information more accessible (emails, meetings, publications on the intranet)</li> <li>-Choose one of the double works and assign new task to the person who is making double results</li> </ul>
Lack of commitment	<ul style="list-style-type: none"> <li>-The tasks are not completed</li> <li>-The project is abandoned</li> </ul>	<ul style="list-style-type: none"> <li>-Meetings</li> <li>-Agreements, energy policy</li> <li>-Establish a check list which must be followed</li> <li>-The awareness of the implementation of the iso must be extended at all levels of the company</li> </ul>	<ul style="list-style-type: none"> <li>-Create a document with the pending tasks.</li> <li>-Try to identify the reason of the lack of commitment</li> <li>-Refresh as often as possible this pending tasks at the meetings</li> <li>-Insist stronger on commitment and show how important is implement ISO 50001</li> </ul>
Illness of a person with many responsibilities	<ul style="list-style-type: none"> <li>-The responsibilities which belongs to that person nobody carries them out</li> <li>-Lack of organization</li> </ul>	<ul style="list-style-type: none"> <li>-Meetings to deliver or delegate the responsibilities between the health workers</li> <li>-Put in charge someone who organize the new situation</li> </ul>	<ul style="list-style-type: none"> <li>-Contract new temporary workers who can take the whole responsibilities an tasks of the ill worker</li> </ul>
Don't use the new tools properly (as software)	<ul style="list-style-type: none"> <li>-The workers ignore that there are new, more efficient tools and, despite being implemented, they do not use them</li> </ul>	<ul style="list-style-type: none"> <li>-Training programmes</li> <li>-Workshops</li> <li>-Establish procedures which includes the new tools</li> </ul>	<ul style="list-style-type: none"> <li>-If the workers tends to do not use this tools, establish more exigent controls (more often, more detailed...)</li> <li>-Refresh workshops</li> </ul>
The management don't support the project until the end	<ul style="list-style-type: none"> <li>-Do not invest enough money</li> <li>-Loose the acceptance by other departments or lower workers</li> <li>-Do not put so enough interest</li> <li>-project failure</li> </ul>	<ul style="list-style-type: none"> <li>-Keep the project as a daily or weekly topic</li> <li>-If it is necessary put in charge a person who controls the development of the project</li> </ul>	<ul style="list-style-type: none"> <li>-If someone realize that the project is about to being dropped, make an emergency meeting with the managers</li> </ul>
Tend to do not tidy the documentation	<ul style="list-style-type: none"> <li>-People who is not involved into the topic will not understand or find any usefull information</li> <li>-Leads to an inefficient way to solve problems (waste of time, money, overview)</li> </ul>	<ul style="list-style-type: none"> <li>-Use software that automates the data</li> <li>-Use an interface to organize a accessible and visual documents</li> </ul>	<ul style="list-style-type: none"> <li>-Check if the interface is efficient and all the people understand it otherwise, change it</li> <li>-Create new patterns and procedures</li> </ul>



## Appendix 3: Motor Specification Sheet

### ELEKTROMATEN® SI

Safedrive®

For driving:  
Roller shutters and rolling grilles  
which require an anti-fallback device

Series SG63F  
SI 10.15 - SI 25.15

Series SG85F  
SI 25.10 - SI 65.15

Series SG115F  
SI 75.10 - SI 180.6

"Safedrive®" ELEKTROMATEN SI are special drives for industrial doors which require an anti-fallback device. The patented safety brake is built into the gear. The drive unit is fitted directly to the door shaft. Safedrive® ELEKTROMATEN comprises of:  
Worm gear with safety brake and hollow shaft, emergency manual operator, integrated limit switches and electrical motor.

#### Patented built-in safety brake

- Safety against failure of worm or wheel
- Independent of speed / direction
- Maintenance free, self-monitoring
- Excellent damping characteristics in operation

#### Approvals and certificates

##### ELEKTROMATEN

Type test according to:  
DIN EN 12453  
DIN EN 60335-1  
DIN EN 60335-2-103  
TUV NORD CERT GmbH



##### Built-in safety brake

Certificate of conformity according to:  
DIN EN 12404 / 12405  
ift Rosenheim GmbH



SG63F



SG85F



SG115F



1



2



3



4

#### Emergency manual operation

- Hand crank NHK
- Hand chain operator KNH

1

2

#### Limit switches

- Mechanical limit NES**
- 2 operating, 2 emergency- and 2 auxiliary limit switches

3

**Digital limit DES**

- Absolute encoder, after a power failure, re-adjustment is not required

4

#### Mounting

- Floating foot (standard fitting)
- Torque bracket
- Moving-torque bracket

#### Special versions

- Increase of movements per hour
- Higher protection class
- Other voltages and frequencies
- Explosion-proof according to ATEX (page 6.0111)
- ELEKTROMATEN SI with built-on frequency inverter (page 1.101)

#### Door controls

- Simple connection by means of non-interchangeable plug connections allowing simple exchange with other GfA control panels
- Control voltage: 24V
- Frequency: 50 / 60 Hz
- Mains supply: 1N-230V, 3-230V, 3N-400V, 3-400V

Details of all GfA door controls can be found in Section 8.

## 1. Technical data

ELEKTROMATEN		SI 10.15	SI 17.15	SI 163 25.15	SI 25.10	SI 25.15WS	SI 40.10	SI 40.15	SI 45.7WS
Series		SG63F	SG63F	SG63F <sup>1</sup>	SG85F	SG85F	SG85F	SG85F	SG85F
Output torque	Nm	100	170	250	250	250	400	400	450
Output speed	rpm	15	15	15	10	15	10	15	7
Output shaft / hollow shaft (Ø)	mm	30	30 / 40	30 / 40	30 / 40	30 / 40	40	40	40
Locking torque <sup>2</sup>	Nm	420	420	510	635	635	760	760	1100
Safety brake (approval number)		14-003612-PR02	14-003612-PR02	14-003612-PR02	14-003612-PR03	14-003612-PR03	14-003612-PR03	14-003612-PR03	14-003612-PR03
Max. holding torque <sup>3</sup>	Nm	170	170	250	250	250	400	400	450
Max. output speed OPEN / CLOSE for frequency inverter operation <sup>4</sup>	rpm	26 / 15	26 / 15	26 / 15	18 / 15	--	18 / 15	26 / 15	--
Motor power	kW	0,30	0,40	0,55	0,55	0,75	0,75	0,85	0,75
Supply voltage	V	3-230 / 400	3-230 / 400	3-230 / 400	3-230 / 400	1N-230	3-230 / 400	3-230 / 400	1N-230
Operating frequency	Hz	50	50	50	50	50	50	50	50
Operating current <sup>5</sup>	A	2,6 / 1,5	3,7 / 2,2	4,0 / 2,3	3,1 / 1,8	8,0	5,1 / 3,0	4,4 / 2,6	8,0
Max. movements per hour <sup>6/7</sup>		20	20	20	20	14	16	16	8
Limit switch range <sup>8</sup>		20	20 (40)	20 (40)	20 (60, 110)	20 (60, 110)	20 (60, 110)	20 (60, 110)	20 (60, 110)
Max. hand force NHK / SK and / or KNH <sup>9</sup>	N	65 / 172	80 / 89	118 / 132	85 / 95	85 / 95	136 / 151	136 / 151	78 / 87
Weight	kg	15	16	19	24	27	26	23	33
Spare parts: Catalogue page		9.054	9.054	9.054	9.055	9.055	9.055	9.055	9.055
Part no. installation drawing (dxf, dwg)		50001039	50001039	50001713	50000580	50000751	50000580	50000580	50001571
Part no. ELEKTROMATEN		Ø30 10003490	Ø30 10003055 Ø40 10003830	Ø30 10003166 Ø40 10003950	Ø30 10002363 Ø40 10004532	Ø30 10002514 Ø40 10002559	Ø40 10002367	Ø40 10002368	Ø40 10003600

ELEKTROMATEN		SI 55.10	SI 55.15	SI 65.10	SI 65.15	SI 75.10	SI 75.15	SI 100.10	SI 140.7	SI 180.6
Series		SG85F	SG85F	SG85F	SG85F	SG115F	SG115F	SG115F	SG115F	SG115F
Output torque	Nm	550	550	650	650	750	750	1000	1400	1800
Output speed	rpm	10	15	10	15	10	15	10	7	6
Output shaft / hollow shaft (Ø)	mm	40	40	40	40	55	55	55	55	60
Locking torque <sup>2</sup>	Nm	1100	1100	1100	1100	2800	2800	2800	2800	3125
Safety brake (approval number)		14-003612-PR03	14-003612-PR03	14-003612-PR03	14-003612-PR03	14-003305-PR01	14-003305-PR01	14-003305-PR01	14-003305-PR01	14-003305-PR01
Max. holding torque <sup>3</sup>	Nm	550	550	650	650	750	750	1000	1400	1800
Max. output speed OPEN / CLOSE for frequency inverter operation <sup>4</sup>	rpm	18 / 18	26 / 26	15 / 15	15 / 15	18 / 18	26 / 26	18 / 18	12 / 12	10 / 10
Motor power	kW	0,75	1,10	0,75	1,10	1,10	1,10	1,30	1,10	1,30
Supply voltage	V	3-230 / 400	3-230 / 400	3-230 / 400	3-230 / 400	3-230 / 400	3-230 / 400	3-230 / 400	3-230 / 400	3-230 / 400
Operating frequency	Hz	50	50	50	50	50	50	50	50	50
Operating current <sup>5</sup>	A	7,2 / 4,2	7,2 / 4,2	7,2 / 4,2	7,2 / 4,2	7,0 / 4,1	8,1 / 4,7	11,2 / 6,5	7,0 / 4,1	11,2 / 6,5
Max. movements per hour <sup>6/7</sup>		16	16	10	12	14	14	12	10	4
Limit switch range <sup>8</sup>		20 (60, 110)	20 (60, 110)	20 (60)	20 (60)	20 (60, 110)	20 (60, 110)	20 (60, 110)	20 (30)	20 (30)
Max. hand force NHK / SK and / or KNH <sup>9</sup>	N	320 / 158	320 / 158	233 / 188	233 / 188	290 / 234	290 / 234	349 / 282	263 / 212	348 / 281
Weight	kg	30	30	33	33	44	42	46	51	54
Spare parts: Catalogue page		9.055	9.055	9.055	9.055	9.056	9.056	9.056	9.056	9.056
Part no. installation drawing (dxf, dwg)		50000734	50000734	50000734	50000734	50000794	50000794	50000794	50000795	50001524
Part no. ELEKTROMATEN		10002479	10002480	10005061	10005062	10002402	10002535	10002536	10002537	10003765

Generally applies: Degree of protection IP65 (combined with WS 900: IP54), permissible temperature range -10°C...+40°C (+60°C), operating sound pressure level SPL <math>70 \text{ dB(A)}</math>

1 Customised designs of the SI 25.15 [e.g. for other voltages] are realised, in part, with the SG85F gearbox series (please contact us, in case of queries) · 2 See 3.5 · 3 Maximum torque that may act on the output shaft of the drive unit when the door is stationary · 4 We recommend the selection of a special GFA ELEKTROMATEN-FI for use with frequency inverter, OPEN drive speed at 87 Hz, see 3.7 · 5 The max. current in door drives can reach up to 4x the rated operating current for limited periods, see 3.6 and 3.7 · 6 When using a temperature range of +40°C...+60°C use half of maximum movements per hour, see also 3.2 · 7 The specified value must be halved when considering cycles per hour according to EN 60335-2-103 · 8 Maximum revolutions of hollow shaft · 9 See 3.4

## 2. Selection chart

Roller shutters Tube EN 10220 [mm]	SI 10.15		SI 17.15		SI 163 25.15		SI 25.10		SI 25.15 WS		SI 40.10		SI 40.15		SI 45.7 WS	
	F [N]	v <sub>s</sub> [cm/s]	F [N]	v <sub>s</sub> [cm/s]	F [N]	v <sub>s</sub> [cm/s]	F [N]	v <sub>s</sub> [cm/s]	F [N]	v <sub>s</sub> [cm/s]	F [N]	v <sub>s</sub> [cm/s]	F [N]	v <sub>s</sub> [cm/s]	F [N]	v <sub>s</sub> [cm/s]
101,6 x 3,6	1316	9,6	2237	9,6	3289	9,6	3289	6,4	3289	9,6	--	--	--	--	--	--
108,0 x 3,6	1250	10,1	2125	10,1	3125	10,1	3125	6,7	3125	10,1	5000	6,7	5000	10,1	5625	4,7
133,0 x 4,0	1046	12,0	1778	12,0	2614	12,0	2614	8,0	2614	12,0	4183	8,0	4183	12,0	4706	5,6
159,0 x 4,5	894	14,1	1520	14,1	2235	14,1	2235	9,4	2235	14,1	3575	9,4	3575	14,1	4022	6,6
177,8 x 5,0	--	--	1375	15,5	2022	15,5	2022	10,4	2022	15,5	3236	10,4	3236	15,5	3640	7,2
193,7 x 5,4	--	--	--	--	1872	16,8	1872	11,2	1872	16,8	2995	11,2	2995	16,8	3336	7,8
219,1 x 5,9	--	--	--	--	--	--	--	--	--	--	2677	12,5	2677	18,8	3011	8,8

Roller shutters Tube EN 10220 [mm]	SI 55.10		SI 55.15		SI 65.10		SI 65.15		SI 75.10		SI 75.15		SI 100.10		SI 140.7		SI 180.6	
	F [N]	v <sub>s</sub> [cm/s]	F [N]	v <sub>s</sub> [cm/s]	F [N]	v <sub>s</sub> [cm/s]	F [N]	v <sub>s</sub> [cm/s]	F [N]	v <sub>s</sub> [cm/s]	F [N]	v <sub>s</sub> [cm/s]	F [N]	v <sub>s</sub> [cm/s]	F [N]	v <sub>s</sub> [cm/s]	F [N]	v <sub>s</sub> [cm/s]
159,0 x 4,5	4916	9,4	4916	14,1	5810	14,1	5810	14,1	6704	9,4	6704	14,1	--	--	--	--	--	--
177,8 x 5,0	4449	10,4	4449	15,5	5258	15,5	5258	15,5	6067	10,4	6067	15,5	8089	10,4	11325	7,2	--	--
193,7 x 5,4	4118	11,2	4118	16,8	4867	16,8	4867	16,8	5615	11,2	5615	16,8	7487	11,2	10482	7,8	13477	6,7
219,1 x 5,9	3680	12,5	3680	18,8	4350	18,8	4350	18,8	5019	12,5	5019	18,8	6692	12,5	9368	8,8	12045	7,5
244,5 x 6,3	3327	13,8	3327	20,8	3932	20,8	3932	20,8	4537	13,8	4537	20,8	6049	13,8	8469	9,7	10888	8,3
273,0 x 6,3	--	--	--	--	3549	23,0	3549	23,0s	4096	15,3	4096	23,0	5461	15,3	7645	10,7	9829	9,2
298,5 x 7,1	--	--	--	--	--	--	--	--	3768	16,7	3768	25,0	5024	16,7	7033	11,7	9042	10,0
323,9 x 7,1	--	--	--	--	--	--	--	--	--	--	--	4653	18,0	6514	12,6	8375	10,8	

■ F = Lift [N]

■ v<sub>s</sub> = Initial speed [cm/s]

■ Includes 20% friction for single-wall profiles (profile thickness 20mm)

■ Read note in 3.2

## 3. Notes

### 3.1 European directive

In accordance with the product standard EN 13241 Doors- and EN 12453 Safety in use of power operated doors-Requirements.

### 3.2 Selection chart / Movements per hour

The specified movements per hour (see Technical data) apply to an even distribution and the limit switch range first mentioned and must not be exceeded. For other limit switch ranges or heavily used doors, the drag forces must be reduced (enquire).

The selection chart includes 20% friction for roller shutters with single-wall profiles (profile thickness 20mm) and 10% friction for sectional doors.

Reduce the weight by a further 20% for vertical lifted doors and insulated shutters with double walled, thick and/or deep sections. Do not calculate using the tube diameter. The highest torque will occur normally after 1-2 turns of the barrel from close.

### 3.3 Gear self-braking / Brake

Drives without an electric brake have a self-sustaining worm gear and stop automatically.

On drives with an electric brake, stopping is achieved by the external brake. Brake inspection must always be carried out by qualified service engineers.

### 3.4 Manual operation

In accordance with EN 12453 and 12604 hand force up to 390 N is permissible. For large, heavy doors, manual operation is only used for closing the door. In the case of drive units with an electric brake; emergency manual operation is carried out against the closed brake (Read note in 3.3).

### 3.5 Locking torque / Holding torque

The permissible loads on walls, fastenings, mountings and transmission elements must not be exceeded, even for maximum holding torques or locking torques.

### 3.6 Motor overload protection

Motor overload protection must be able to withstand 4x the operating motor current because the starting current of the drive unit can reach these levels for short periods.

### 3.7 Use with external frequency inverter

We recommend ELEKTROMATEN FI with an integrated frequency inverter (page 1.101).

For external frequency inverters applies:

A higher than recommended drive speed puts extra load onto the gear. This extra load must be taken into account when sizing a drive by reducing the available output torque.

Increasing the drive speed by 10% reduces the admissible drive torque by 5%. In the case of higher drive speeds reduce the drive torque accordingly (enquire if necessary).

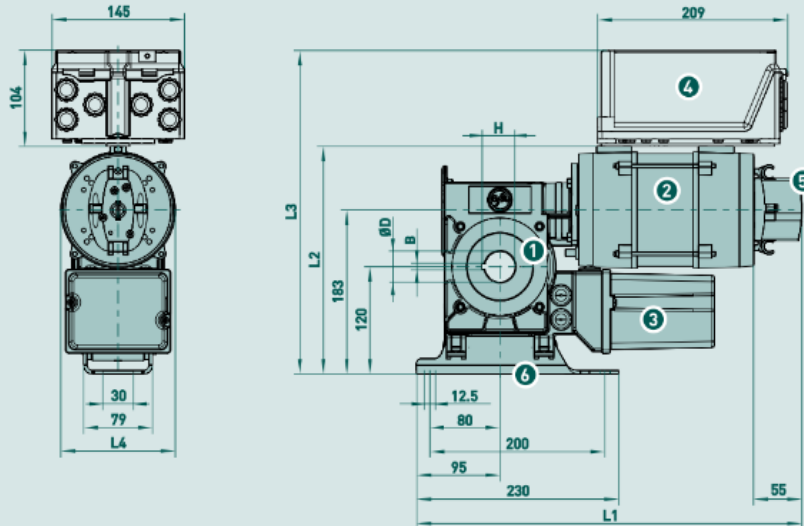
The admissible drive speeds may not be exceeded (see Technical data). The operating forces must comply with EN 12453, and the corresponding EMC directives must likewise be observed.

If selecting a frequency inverter, note that the starting current of the drive unit can reach 4x the operating motor current.

## 4. Dimensions

### 4.1 SI 10.15 – SI63 25.15

SG63F



Ø D	H	B
30	33,3	8
40	43,3	12

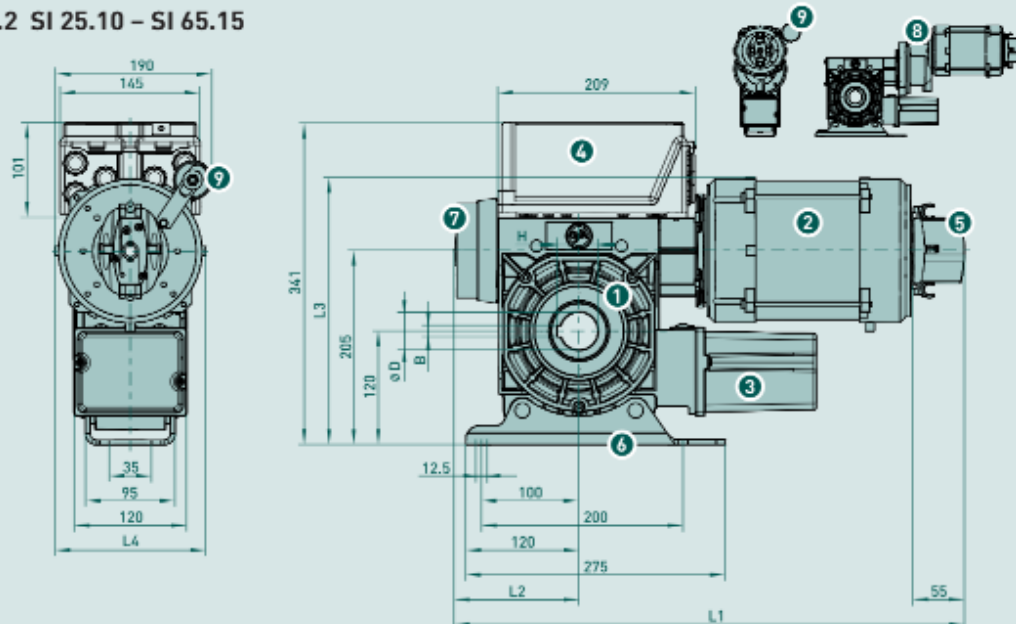
- 1 Worm gear with safety brake
- 2 Motor
- 3 Limit switch
- 4 Optional: WS 900 control panel, removable, with 0,8m cable
- 5 Hand crank NHK
- 6 Floating foot

ELEKTROMATEN	L1	L2	L3	L4
SI 10.15	422	246	348	105
SI 17.15	432	244	348	105
SI63 25.15	445	254	358	131

- Permitted installation: Horizontal (as shown) or vertical (motor at the bottom)
- Customised designs of the SI 25.15 are realised, in part, with the SG85F gearbox series (see 4.2, please contact us, in case of queries)

### 4.2 SI 25.10 – SI 65.15

SG85F



- 1 Worm gear with safety brake
- 2 Motor
- 3 Limit switch
- 4 Optional: WS 900 control panel, removable, with 0,8m cable
- 5 Hand crank NHK
- 6 Floating foot
- 7 Brake
- 8 Intermediate gear
- 9 Capacitor

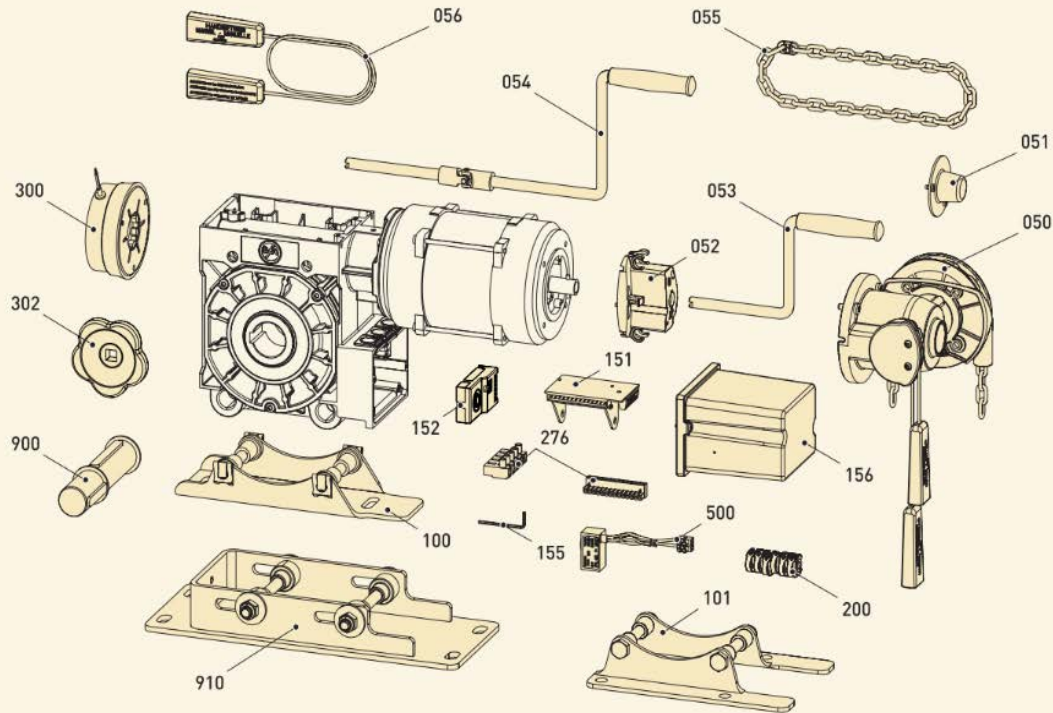
ELEKTROMATEN	Ø D	H	B	L1	L2	L3	L4
SI 25.10	30	33,3	8	497	120	271	130
SI 25.15 WS 9	30	33,3	8	524	120	281	152
SI 40.10	40	43,3	12	520	120	271	130
SI 40.15	40	43,3	12	487	120	271	130
SI 45.7 WS 8 9	40	43,3	12	625	120	337	152
SI 55.10 7	40	43,3	12	535	131	281	152
SI 55.15 7	40	43,3	12	535	131	281	152
SI 65.10 7	40	43,3	12	535	131	281	152
SI 65.15 7	40	43,3	12	535	131	281	152

- Permitted installation: Horizontal (as shown) or vertical (motor at the bottom)



# Spare parts

Series  
SG85



Pos.	Designation	Part no.	
050	Emergency operation <sup>1,2</sup>	KNH Hand chain operator 4m for: KE 20.24 / SI 8.200 FI / SI 10.70 / SI 10.160 FI / SI 10.200 FI / SI 13.70 / SI 15.140 FI / SI 20.100 FI / SI 25.10 / SI 25.15 / SI 25.15 WS / SI 40.10 / SI 40.15 / SI 45.7 WS  KNH Hand chain operator 4m for: KE 30.24 / KE 40.24 / SI 12.140 FI / SI 15.120 FI / SI 20.90 / SI 25.24 / SI 25.35 / SI 25.60 / SI 25.60 FI / SI 25.80 FI / SI 25.150 FI / SI 35.30 / SI 35.100 FI / SI 40.24 / SI 40.40 FI / SI 45.60 FI / SI 55.10 / SI 55.15 / SI 55.40 FI	20002862.00032  20002862.00042
051	Motor cover	20002862.00000	
052	Hand crank switch <sup>1</sup>	20002862.00011	
053	Hand crank	30002749	
054	Hand crank with knuckle joint	30002750	
055	Hand chain extension	4m 30004555.00004 6m 30004555.00006	
056	Shifter cable extension	2x4m 30003965	
100	Assembling kit	Floating foot 20002494.00001	
101		Foot angle 20002494.00006	
151	Limit switch unit	NES 6 micro / 7 micro 30003040 / 30003041	
152		DES 4 30004757	
155	Hex wrench	40000148	
156	Cover <sup>1</sup>	30004298	
200	Assembling kit limit cams	6 micro 20002496.00001	
276	Connection plugs	14/5-pole for NES 30003380	
300	Brake unit	9Nm, 102V/130V <sup>3</sup> 20002959.09004	
302	Hand wheel	for ST drive units 30004098	
500	Rectifier EGR II <sup>3</sup>	only for drive units with brake 20003369.00001	
900	Stub shaft cpl.	Ø 40mm 30002637	
910	Bracket SG85 cpl.	30005055	

## Appendix 4: BURNT PLA PROPERTIES

Poly(lactic acid) or polylactide (PLA) is a polymer made up of molecules of lactic acid, with properties like those of polyethylene terephthalate (PET) used to make packaging, but which is also biodegradable. It easily degrades in water and carbon dioxide.

It is a thermoplastic that is obtained from corn starch (USA) or cassava or manioc (mostly in Asia), or sugarcane (rest of the world).

It is widely used in 3D printing under the FDM process. The second largest producer of PLA worldwide is the Weforyou group with an annual capacity of pure PLA and compounds of 50,000 tons.

As a thermoplastic it is a material that at relatively high temperatures, becomes deformable or flexible, melts when heated and hardens in a glass transition state when cooled sufficiently. Most thermoplastics are high molecular weight polymers, which have associated chains by means of weak van der Waals forces (polyethylene); strong dipole-dipole and hydrogen bonding interactions, or even stacked aromatic rings (polystyrene). Thermoplastic polymers differ from thermoset polymers or thermosets in that after heating and moulding can overheat and form other objects.

An important property of thermoplastic polymeric materials is their thermal behaviour, since it allows carrying out different processes of their conformation.

In general, the temperature influences the viscoelastic behaviour in the sense of influencing the links by Van der Waals forces between the chains. When the temperature increases, the bonds unwind, and the viscous flow takes place more easily with less applied tension. At low temperatures, the polymer becomes viscous, the chains do not slip, and the polymer exhibits a rigid solid behaviour.

These behaviours are reflected in Figure 1, depending on the temperature and structure, functional groups, of the polymer chain and forming other objects.

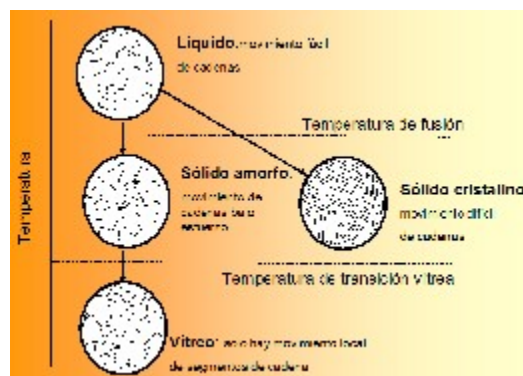
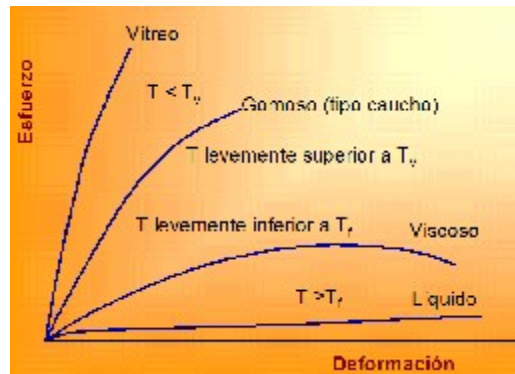


Figure 1.

However, at very high temperatures, the covalent bonds of the main chain can be destroyed, the polymer burns or carbonizes. This temperature, called the degradation temperature, limits

the utility of the polymer and represents the temperature above which the polymer can be usefully shaped.

When the temperature of the linear polymers is high, the viscosity is low. The chains can move easily even without external forces, and if a tension is applied, the polymer flows practically without elastic deformation. The behaviour exhibited is reflected in Figure 2, in which the resistance and modulus of elasticity are almost zero. However, when we lower the temperature, the viscosity increases, and the chains do not move easily, until we reach the melting temperature at which the polymer becomes rigid.



## Appendix 5: CLUTCH FAILURES

In this appendix the mechanical engineers intend to expose the reasons for failures suffered of the piece used as a connector between the motor and the shaft of the crusher throughout the different tests. As it has been specified in the main body of this report, the function of this piece is to connect and transmit the rotation movement from the motor to the axis of the crusher. This piece undergoes a large amount of torsional force and caused many prototypes to fail. Initially a conceptual prototype was made of PLA which was strong enough to shred small pieces of PLA. Once large pieces were placed in the shredder, the part failed as shown in Figure 1.



*Figure 1. Prototype 1*

As can be seen in the image, the fracture occurs in a section change in which tensions are concentrated in components subjected to cyclic stresses, as in this case. After this first test it was decided to continue with the idea of using the PLA, so slight modifications were made to the component to make the critical section slightly larger and in turn more resistant to torsional stress.



*Figure 2. Prototype 2 Which Failed in the Same Manner as Prototype 1*

After not getting a sufficiently strong section the team of mechanical engineers, decided to make some holes in the part to reinforce the adapter with M8x80 screws. This way the metal bolts would increase the strength of the part. While this improved the strength of the components slightly, the part failed due to the decrease in cross-sectional surface area.





*Figure 3. Prototype 3*

After this failure the piece was completely redesigned, making a one-piece adapter with a larger radius to generate more resistant sections, and a progressive variation was made in the section change to reduce the stress concentrations.



*Figure 4. Prototype 4*

In this case, a fracture occurred in the area where two orifices had been made where two screws were inserted to connect the clutch to the motor shaft. It was decided to slightly separate these holes and again expand the radius of the sections a little more. Thus, a prototype was obtained in functional PLA, which successfully passed the tests.



*Figure 5. Prototype 5*

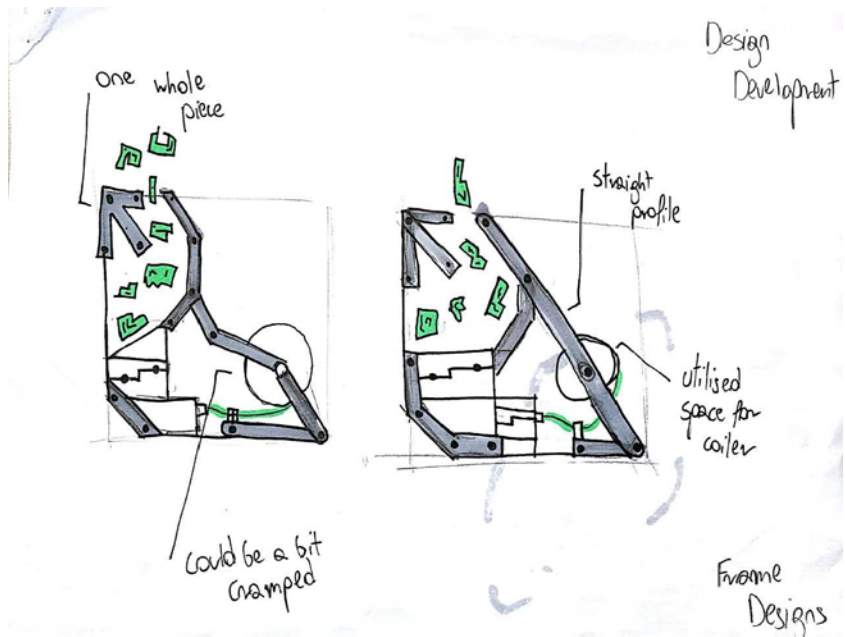
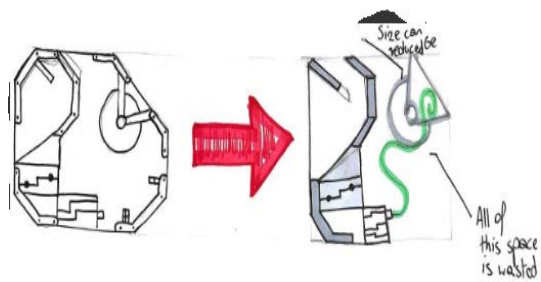
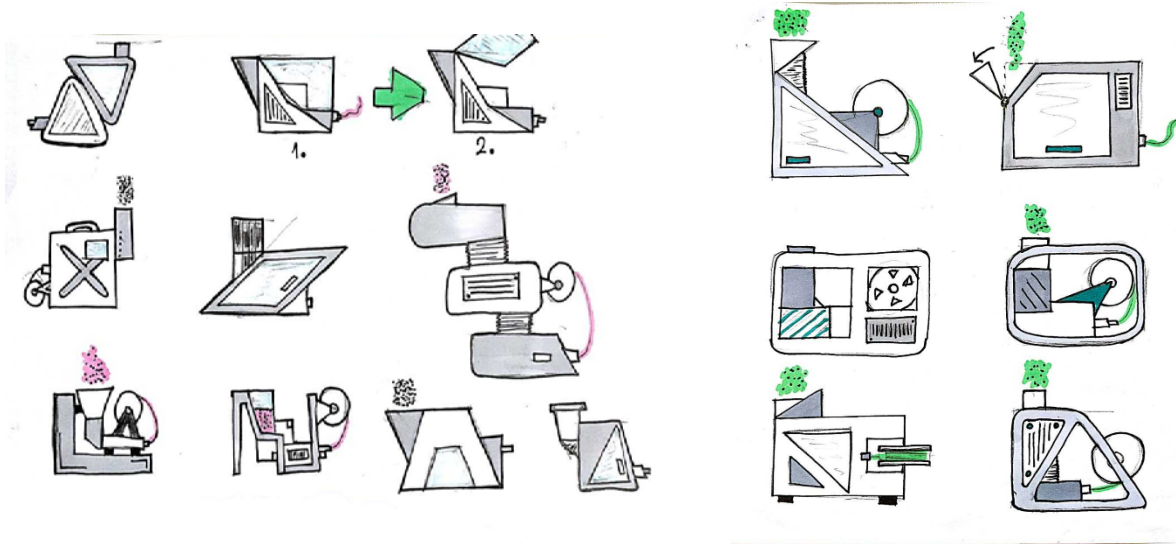
Finally, after verifying that this last design worked correctly, it was decided to manufacture in steel in the Avans workshop, obtaining the definitive piece used in the final design.

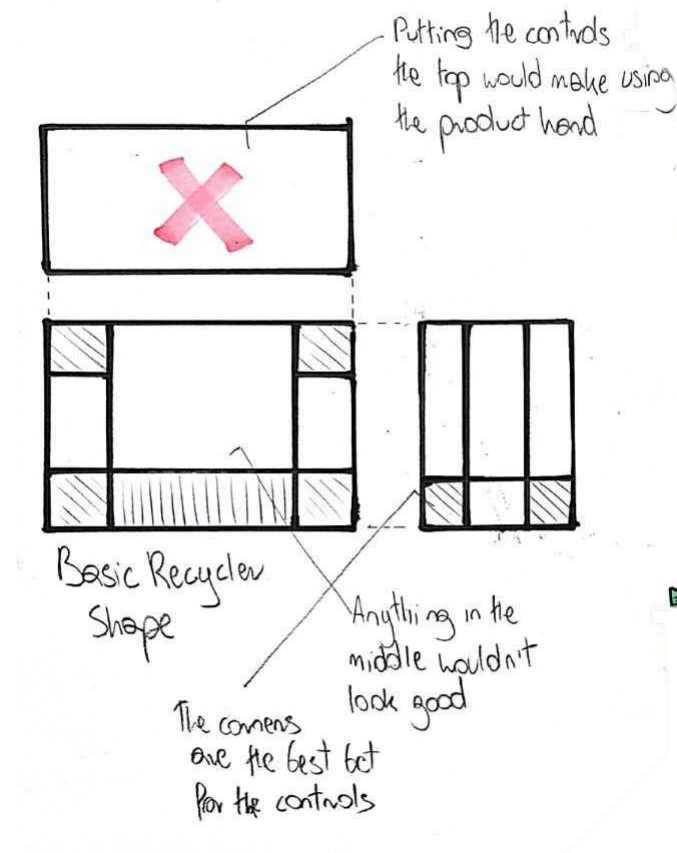
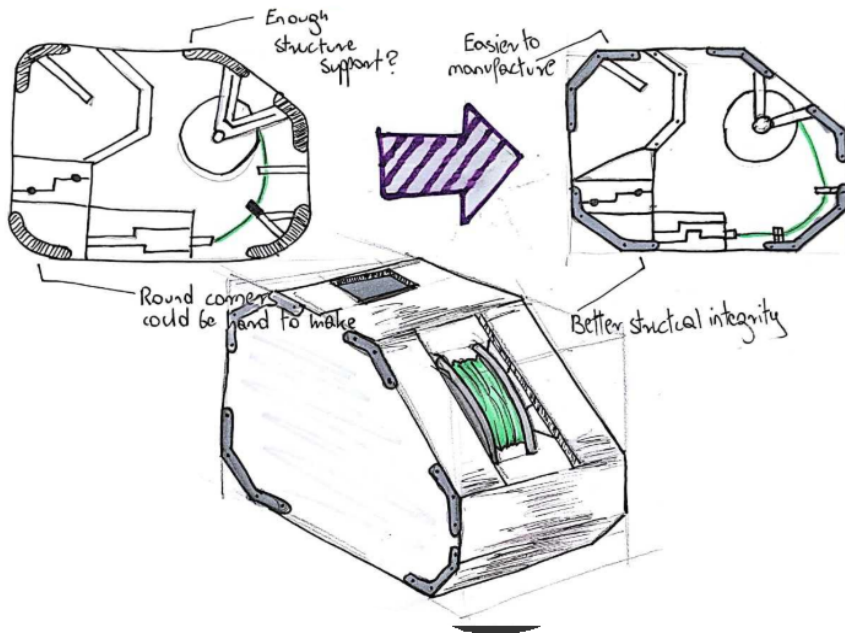


*Figure 6. Prototype 6*

## Sketch Pages

These sketch pages are topical to the report and do not include all of the Design process. The whole design development is a separate document available for viewing at the final presentation.





## Appendix 7: PYTHON PROGRAM

First, the needed Python libraries are imported. A library is a previously written code that allows the programmer not having to start from the very beginning when writing a new program. RPi.GPIO allows a simple control of the in- and output pins of the Raspberry. The time module is used here to time delays when activating motors and multiprocessing allows Python to run two parts of the script at the same time.

```
import RPi.GPIO as GPIO
import time
import multiprocessing as mp
```

Further, the program is initialized and the in- and output pin numbers which are connected to the components are stored as text-variables to make it easier to read later. “#” are used for commenting within the code, these lines will be skipped by the interpreter.

```
# init pins
GPIO.setmode(GPIO.BCM)

motor_1_pin = 18
motor_2_pin = 17
fan_pin = 27

thermometer_pin = 7 # must be GPIO 4
heater_pin = 22
servo_pin = 25
stepper_pins = [5, 6, 13, 19]
light_sensor_pin = 26

## LED pins
pin_up = 23
pin_down = 24
rot = 16
grun = 20
blau = 21

# further v
sleep = 0.1
level = 1
stepper_turns = 0
turns_weight = 0.125
coiler_rows = 30
coiler_layers = 20
```

In the following section the user may choose if an external PID controller will be used and if not, choose the desired setpoint of the heating temperature.

```
PID_by_Python = 0 #set "1" if not using external PID controller
pla_temperature = 195 #Degrees Celsius # PID setpoint
```

```
def PID_by_Python(switch):
    if switch == 1
        process_PID.start()
    else:
        None
```

The following part contains all the classes and methods that the main program will refer to. Class switch mode defines how to deal with the input via the two buttons that are used to switch between the three main operating levels.

```
class switch_mode:
    def __init__(self, pin_up, pin_down):
        self.pin_up = pin_up
        self.pin_down = pin_down

    def up(pin_up):
        global level
        if level == 3:
            None
        else:
            level = level+1
            mode(level)

    def down(pin_down):
        global level
        if level == 1:
            None
        else:
            level = level-1
            mode(level)
```

The LED class changes the color of the LED to indicate the operating mode.

```
class LED():
    def blue():
        GPIO.output(rot,0)
        GPIO.output(grun,0)
        GPIO.output(blau,1)
    def yellow():
        GPIO.output(rot,1)
        GPIO.output(grun,1)
        GPIO.output(blau,0)
    def red():
        GPIO.output(rot,1)
        GPIO.output(grun,0)
        GPIO.output(blau,0)
    def green():
```

```
GPIO.output(rot,0)
GPIO.output(grun,1)
GPIO.output(blau,0)
```

These subclasses are stored in three classes, sorted by the three big components of the final product. The argument “switch” is used to pass either a 0 or a 1 to the method to activate or deactivate the output. The PID class makes use of a PID controller and a thermometer reader library that are preinstalled on the delivered Raspberry Pi.

For the servomotor, PWM is used to pass the desired position. The motor adjusts to the duty cycle of the single-phase alternating current generated by the Raspberry Pi. Whenever a given limit (v\_left or v\_right) is reached, it changes its direction. The step size depends on the input of the user, the amount of filament that can be rolled up before the direction should be changed.

The stepper motor is run in half step mode for a given angle, every time the light sensor is triggered. With the use of the H-bridge driver the program is directing external 12V to the different coils within the motor.

In the light sensor method it is defined that the activation of the light sensor leads to activating both coiler motors for a given sequence.

```
class components:
    class crusher:
        def motor_1(switch):
            GPIO.output(motor_1_pin, switch)

    class extruder:
        def motor_2(switch):
            GPIO.output(motor_2_pin, switch)
        def fan(switch):
            GPIO.output(fan_pin, switch)

    class PID_control:
        def setup_PID():
            from simple_pid import PID #controller
            from w1thermsensor import W1ThermSensor
            pla_temperature = 210 #Degrees Celsius
            pid = PID(1, 0.1, 0.05, setpoint = pla_temperature)
            ct = get_temperature()
        def get_temperature():
            sensor = W1ThermSensor()
            current_temperature = sensor.get_temperature()
            return current_temperature
        def heater(switch):
            GPIO.output(heater_pin, switch)
        def PID(switch):
            while switch == 1:
                control = pid(ct) # compute new output from the
                PID according to the thermometers current value
                components.extruder.PID_control.heater(control)
```

```
# feed the PID output to the system and get its current value
```

```
class coiler:
    class servo:
        def setup_servo():
            frequency_hertz = 50
            pwm = GPIO.PWM(servo_pin, frequency_hertz)
            rows_per_roll = coiler_rows
            step = rows_per_roll/1000
            count = 0
            sleep = 0.05
            d = 1
            v_right = 5.5
            v_left = 8.5
            v = v_right
            pwm.start(v)
        def servo():
            while (GPIO.input(light_sensor_pin) == True):
                if d == 1:
                    pwm.start(v)
                    print(v)
                    v = v + step
                    time.sleep(sleep)
                    if v > v_left:
                        d = 0
                else: #d == 0
                    pwm.start(v)
                    print(v)
                    v = v - step
                    time.sleep(sleep)
                    if v < v_right:
                        d = 1

    def stepper():
        halfstep_seq = [
            [1,0,0,0],
            [1,1,0,0],
            [0,1,0,0],
            [0,1,1,0],
            [0,0,1,0],
            [0,0,1,1],
            [0,0,0,1],
            [1,0,0,1]
        ]

        for i in range(512*turns_weight):
            for halfstep in range(8):
                for pin in range(4):
                    GPIO.output(stepper_pins[pin],
halfstep_seq[halfstep][pin])
                    time.sleep(0.001)
                stepper_turns += 1

    def lightsensor(switch):
```



```

while switch == 1:
    if (GPIO.input(light_sensor_pin) == True):
        components.coiler.stepper()
        process_servo.start()

    else:
        print('Not Coiling')
        time.sleep(0.1)

```

As explained in the final outcome part, the three different modes and the activation of the corresponding components are defined.

```

def mode(level):

    if level == 1:
        LED.blue()

        #components.extruder.PID(0)
        process_PID.start()
        process_PID.terminate()
        components.crusher.motor_1(0) #turn off for leveling down
        components.extruder.motor_2(0)
        components.extruder.fan(0)
        components.coiler.light_sensor(0)

        process_PID.start()
        process_servo.terminate()

    if level == 2:
        LED.red()

        PID_by_Python(PID_by_Python)
        components.crusher.motor_1(0)
        components.extruder.motor_2(0)
        components.extruder.fan(0)
        components.coiler.light_sensor(0)

        process_PID.start()
        process_PID.terminate()

    if level == 3:
        LED.green()

        process_PID.start()
        components.crusher.motor_1(1)
        components.extruder.motor_2(1)
        components.extruder.fan(1)
        components.coiler.light_sensor(1)

```

The in the initializing phase defined pins are now set to either in- or output pins. Through the use of "add\_event\_detect", a functionality of the GPIO library, the Raspberry is notified when a button is pressed. This avoids checking the button in an infinite loop for changes.

```
GPIO.setup(motor_1_pin, GPIO.OUT)
GPIO.setup(motor_2_pin, GPIO.OUT)
GPIO.setup(fan_pin, GPIO.OUT)
GPIO.setup(thermometer_pin, GPIO.IN)
GPIO.setup(heater_pin, GPIO.OUT)
GPIO.setup(servo_pin, GPIO.OUT)
GPIO.setup(light_sensor_pin, GPIO.IN)
for pin in stepper_pins:
    GPIO.setup(pin, GPIO.OUT)

GPIO.setup(pin_up, GPIO.IN)
GPIO.setup(pin_down, GPIO.IN)
GPIO.setup(rot, GPIO.OUT)
GPIO.setup(grun, GPIO.OUT)
GPIO.setup(blau, GPIO.OUT)

GPIO.add_event_detect(pin_up, GPIO.RISING, callback = switch_mode.up,
bouncetime=1000)
GPIO.add_event_detect(pin_down, GPIO.RISING, callback =
switch_mode.down, bouncetime=1000)

components.extruder.setup_PID()
components.coiler.setup_servo()

#multiprocessing
process_PID = mp.Process(target = components.extruder.PID_control.PID,
args = (1,))

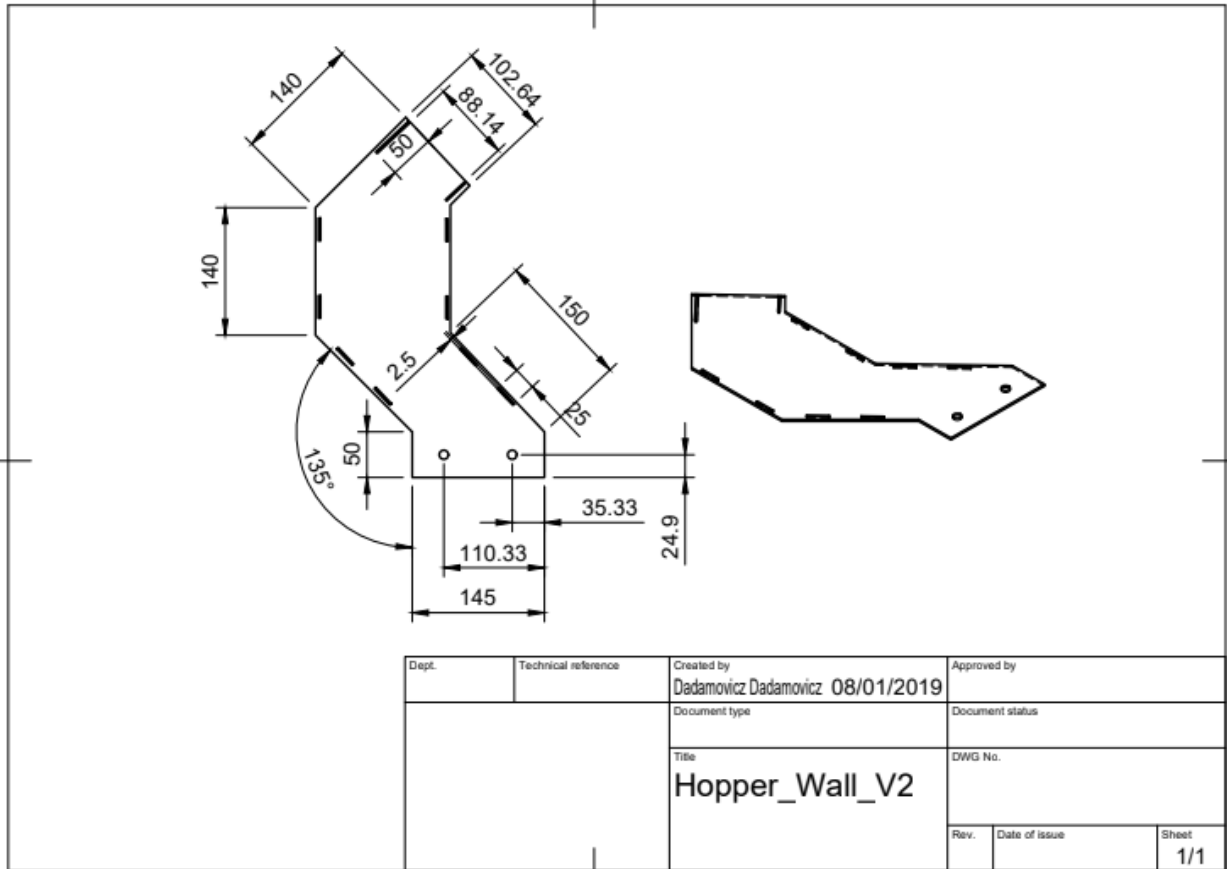
In the end, an constantly repeating loop is started. It keeps running until the maximum capacity
of the coil is used. In case a full roll is achieved, all processes terminate.

LED.blue()

try:
    while (stepper_turns*turns_weight) < (coiler_rows*coiler_layers):
        print ("running level:", i)
        time.sleep(sleep)

except KeyboardInterrupt:
    GPIO.cleanup()
    process_PID.terminate()
    print("cleaned up")
```

## Appendix 8: Plexiglas Drawing



## Appendix 9: MANUFACTURING COSTS

This appendix describes the manufacturing costs of the prototype that the project team presents. As shown below the prices have been broken down, distinguishing the four main parts of which the device consists: hopper, crusher, extruder and coiler.

Manufacturing Costs							
Hopper		Crusher		Extruder		Coiler	
Plexiglass	18 €	Shredder	144 €	Extruder	315 €	Servo motor	8 €
PLA Printings	41 €	Motor	80 €	PLA Printings	2 €	Step motor+driver	17 €
		Clutch	12 €			Light sensor	4 €
<b>Total</b>	<b>59 €</b>	<b>Total</b>	<b>236 €</b>	<b>Total</b>	<b>317 €</b>	<b>Total</b>	<b>29 €</b>

Table 1. Manufacturing costs

The cost of the 3d prints has been made based on the printing cost mentioned in chapter 1 of the report. This cost is € 3.42 for every five hours of printing, neglecting the other costs mentioned in this chapter. Therefore, the cost of printing per hour that we are going to use is € 0.684.

In the nozzle the number of hours of printing that have been estimated is 60 hours, while in the extruder is 3 hours. Finally, in the coiler the costs of printing have been neglected since they are minimal.

The costs of building the shredder can be divided as follows:

### Bill of materials shredder

Description	Material	Details	Quantity	Where to get it	Remarks	Price
<b>Machine parts</b>						
3mm sheet	steel	cutted	1x	Scrapyard/Hardware store	optional stainless steel	30
5mm sheet	steel	cutted	1x	Scrapyard/Hardware store	optional stainless steel	40
6 mm sheet	steel	cutted	1x	Scrapyard/Hardware store	optional stainless steel	40
● Hexagon bar	Steel	27M	32cm	Metal shop		15
L Angle profile	Steel	30x30x3mm	100cm	Scrapyard		10
Mesh	metal	150x180x1.5mm		Scrapyard	perforated sheet or drill holes yourself	2
Sheet metal	Steel	1mm		Scrapyard		7
<b>Electronics</b>						
Motor	-	+/- 2kw	1x	Scrapyard	preferable +/- 70 RPM	30
Power switch	-		1x	Scrapyard/Hardware store		3
Led indicator	-	220V	1x	Hardware store		3
Powercord	-		5 M	Scrapyard/Hardware store		
				<b>Total</b>		<b>€180</b>
						<small>Price varies depending on where you live</small>

Additionally, the costs of the aluminum bars and the connectors that have been used must be added, which is 45 euros extra and the price of the Raspberry Pi which is € 35. So, the final cost of manufacturing the prototype is as follows:

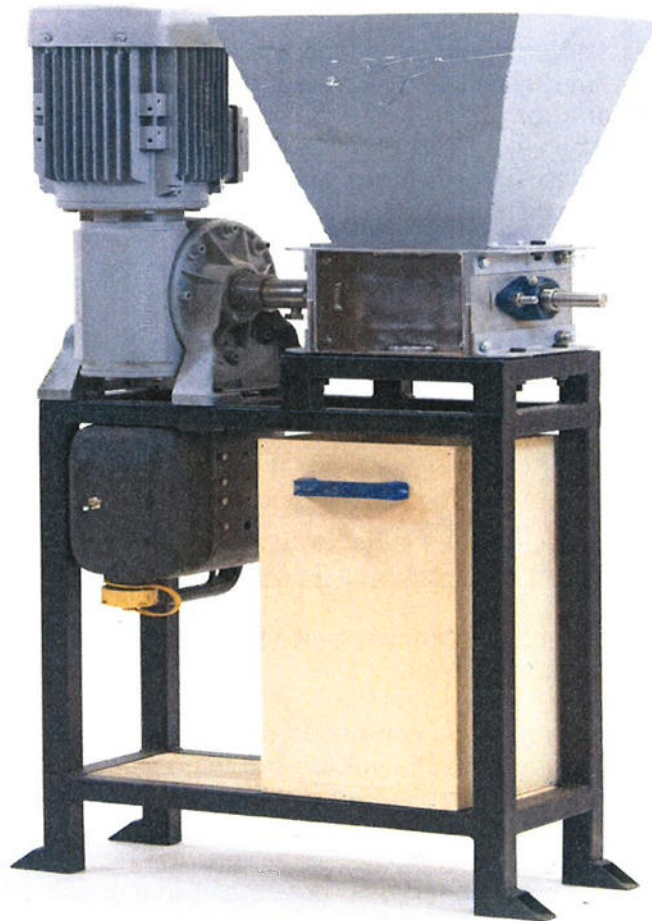
$$€ 59 + € 236 + € 317 + € 29 + € 45 + € 35 = € 701$$

Chapter 5.5 suggests innovations that would improve the device significantly, but in the same way increase the price of the product.

**avans**  
*hogeschool*

Mechanische technieken

# Project shredder



### **Werkvoorbereiding.**

Je gaat tijdens de eerste les een werkvoorbereiding maken van alle onderdelen (mono tekeningen) die de shredder bevat.

De werkvoorbereiding bevat de te zagen of te knippen lengte, de bewerkingsmethode met de daarbij behorende parameters.

Zie hiervoor de werkvoorbereidingsbladen in de bijlage.

### **Productieplanning.**

Je maakt tijdens de eerste les een gedetailleerde productieplanning t.b.v. het fabriceren van de shredder. Hierin vind je persoon, machine en tijd terug.

Denk ook aan de volgorde van bewerkingen.

Indien je van de planning afwijkt draag je er zorg voor dat voor aanvang van de volgende les de planning weer actueel te is.

### **Fabricage.**

Werk volgens je planning en werkvoorbereiding.

Werk veilig en geconcentreerd.

Bij twijfel of vragen richt je je tot een instructeur.

### **Assemblage.**

Geef het monteren en uitlijnen van bepaalde onderdelen voldoende aandacht.

Ook het hechten en aflassen van het onderstel vereist een plan.

Bij de tekeningen vindt je waar nodig aanvullende informatie.

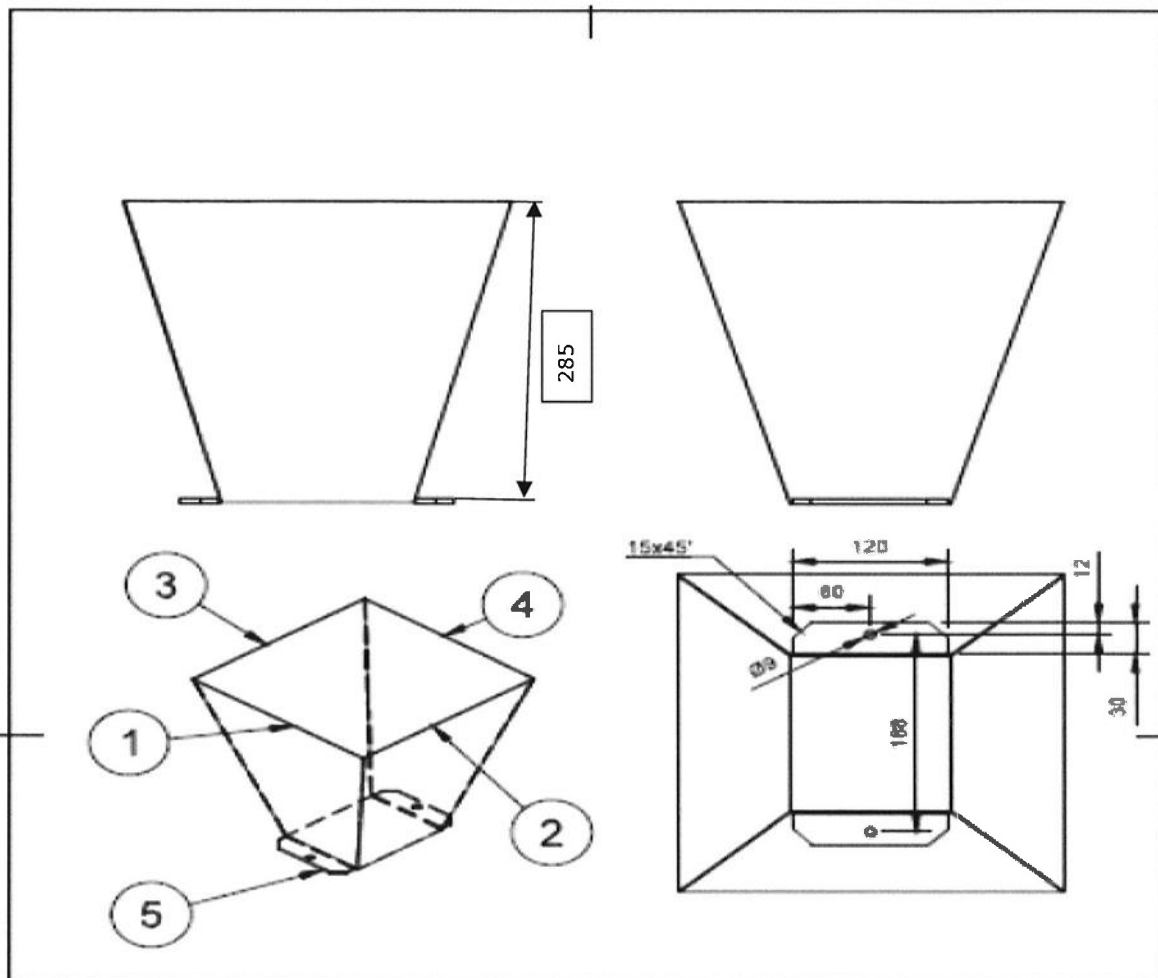
**Veel succes!**

De shredder bestaat uit grofweg 3 assemblies.


- Het onderstel waarop de motor en shredder gemonteerd wordt.
- De shredder.
- De elektromotor met overbrenging.
- De elektromotor wordt gekoppeld middels een flexibelle koppeling.
- Het is belangrijk dat de aandrijfvas van de shredder en de elektromotor netjes uitgelijnd zijn. Hiervoor is er een hulpframe gemaakt tussen het onderstel en de shredder (rood omcirkeld), dit onderstel wordt vervangen door 4 afstandbussen, op de juiste lengte, die het hoogteverschil opvangen.
- De elektromotor en de shredder worden bevestigd op kokers die in het bovenzvlak van het onderstel gelast worden. Let hier op de goede plaatsbepaling en vlakheid. Deze kokers en plaats hiervan zijn niet in de tekening aangegeven, neem deze over van het model dat aanwezig is. **Maatvoering in tekening**

## De hopper.

Zoals je ziet is de hopper opgebouwd uit meerdere onderdelen.  
 Omdat dit productietechnisch niet erg slim is gaan jullie deze maken uit 2 onderdelen.  
 De maatvoering dient gelijk te blijven en de hopper wordt uit 2 onderdelen gemaakt.  
 Maak gebruik van het puntlasproces om deze 2 delen te bevestigen.

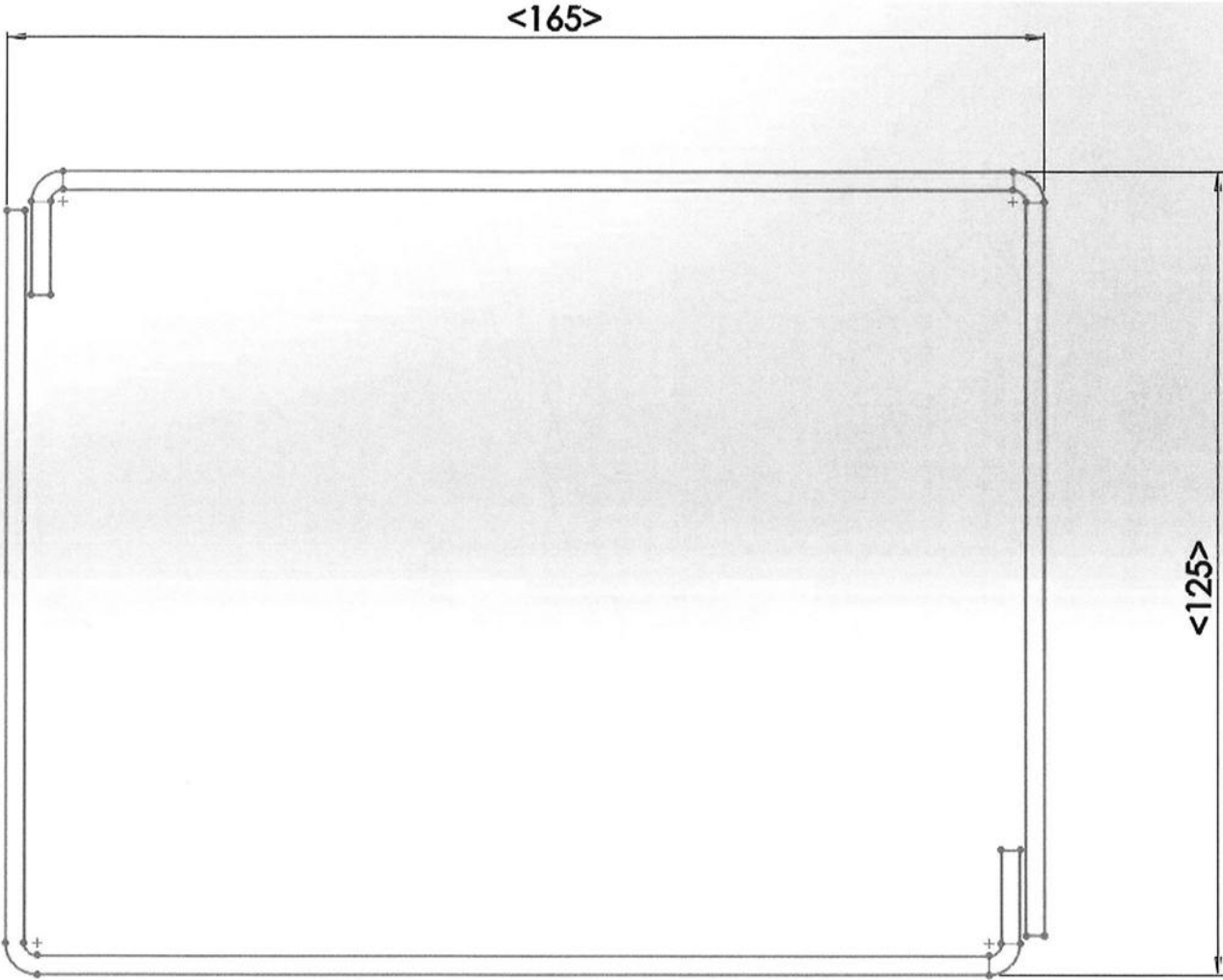


5	2	Bracket	Flat 30x30x3 L=120	Steel
4	1	Side(Mirror)	01,04,24	Steel
3	1	Front(Mirror)	01,04,24	Steel
2	1	Front	01,04,24	Steel
1	1	Side	01,04,24	Steel
Item	Qty	Part Number	Description	Material

Parts List			
Dept <b>Shredder</b>	Technical reference <b>Website</b>	Created by <b>Precious Plastic</b>	Approved by <b>Dave Hakkens</b>
		Document type <b>sizes in mm</b>	Document status <b>scale 1.5</b>
		Title <b>Hopper Assembled</b>	DWG No. <b>V2.0</b>
Rev. <b>A4</b>	Date of issue <b>10-03-2016</b>	Sheet <b>10/11</b>	



**Maatvoering onderzijde hopper.**

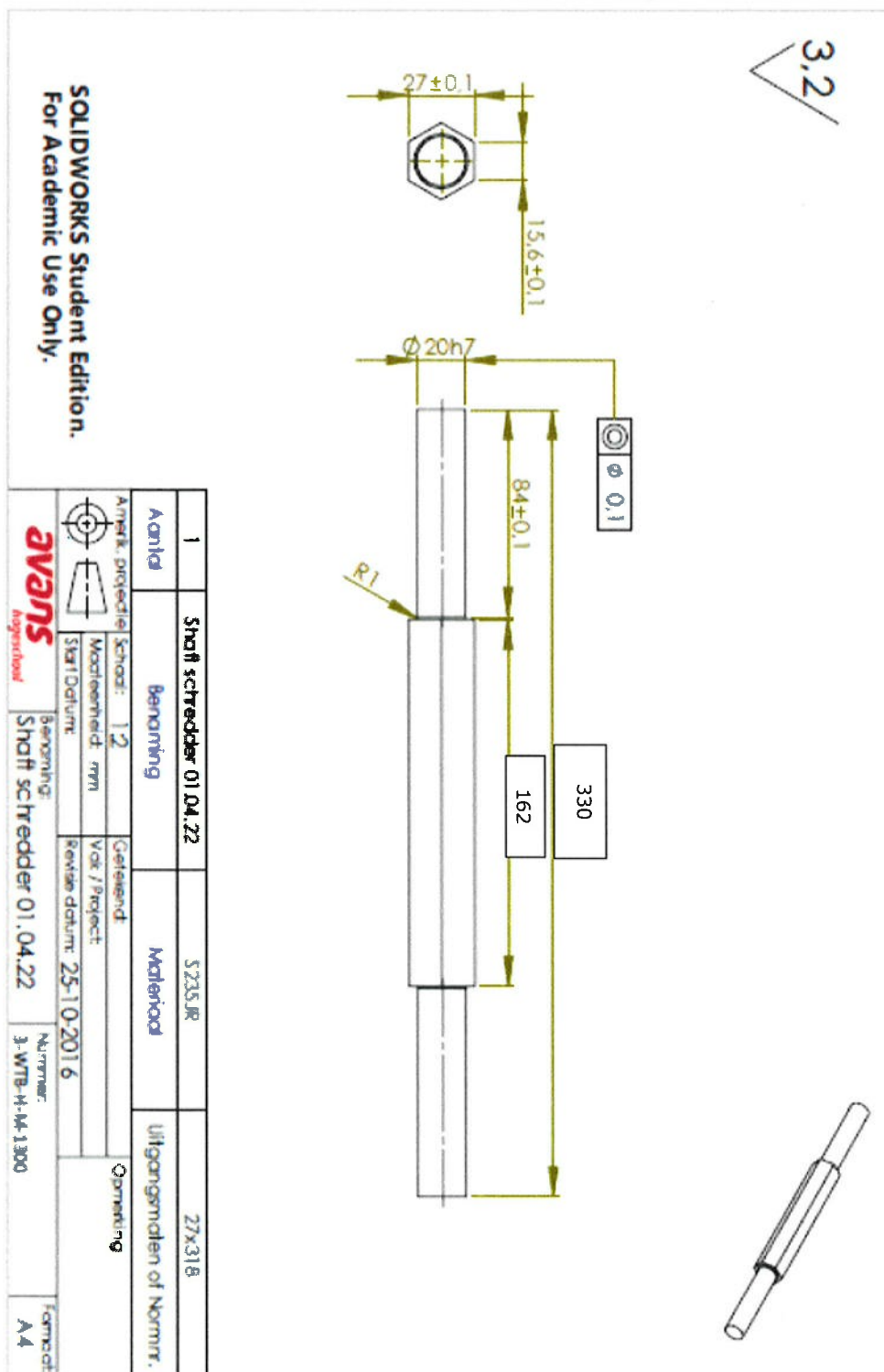


### De hoofdas van de shredder

Op de as worden de knifes en spacers gemonteerd.

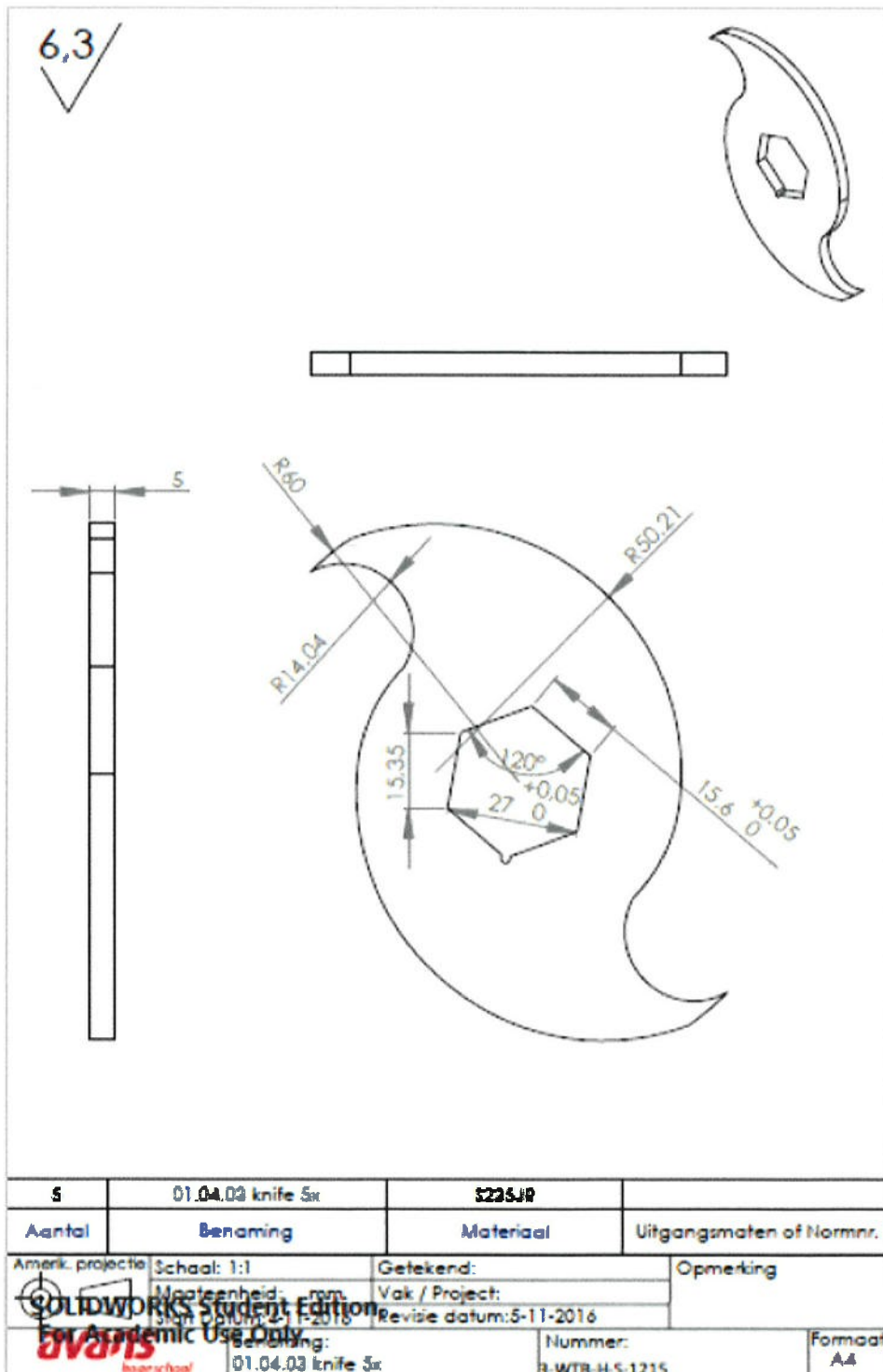
Bepaal wat de aanduiding **h7** voor tolerantie is op de maat van  $\varnothing 20$ .

Aan deze zijde van de as moet ook een spiebaan gefreesd worden, bepaal hiervan de afmetingen.



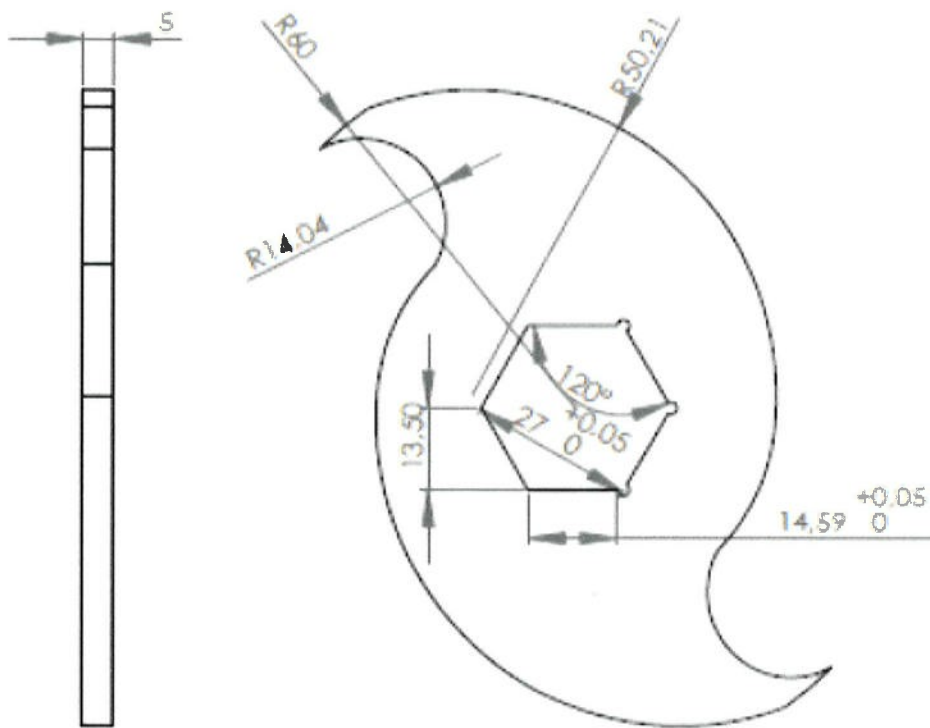
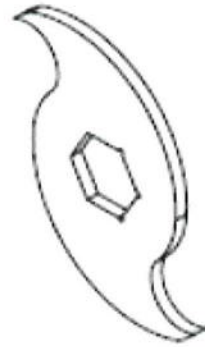
### Knife.


Van de knifes hebben we er van elk 5 stuks nodig. Er zijn 3 soorten, kijk zelf wat er anders aan is. Ook hierbij geldt, duurzame plaatindeling!



9

6,3

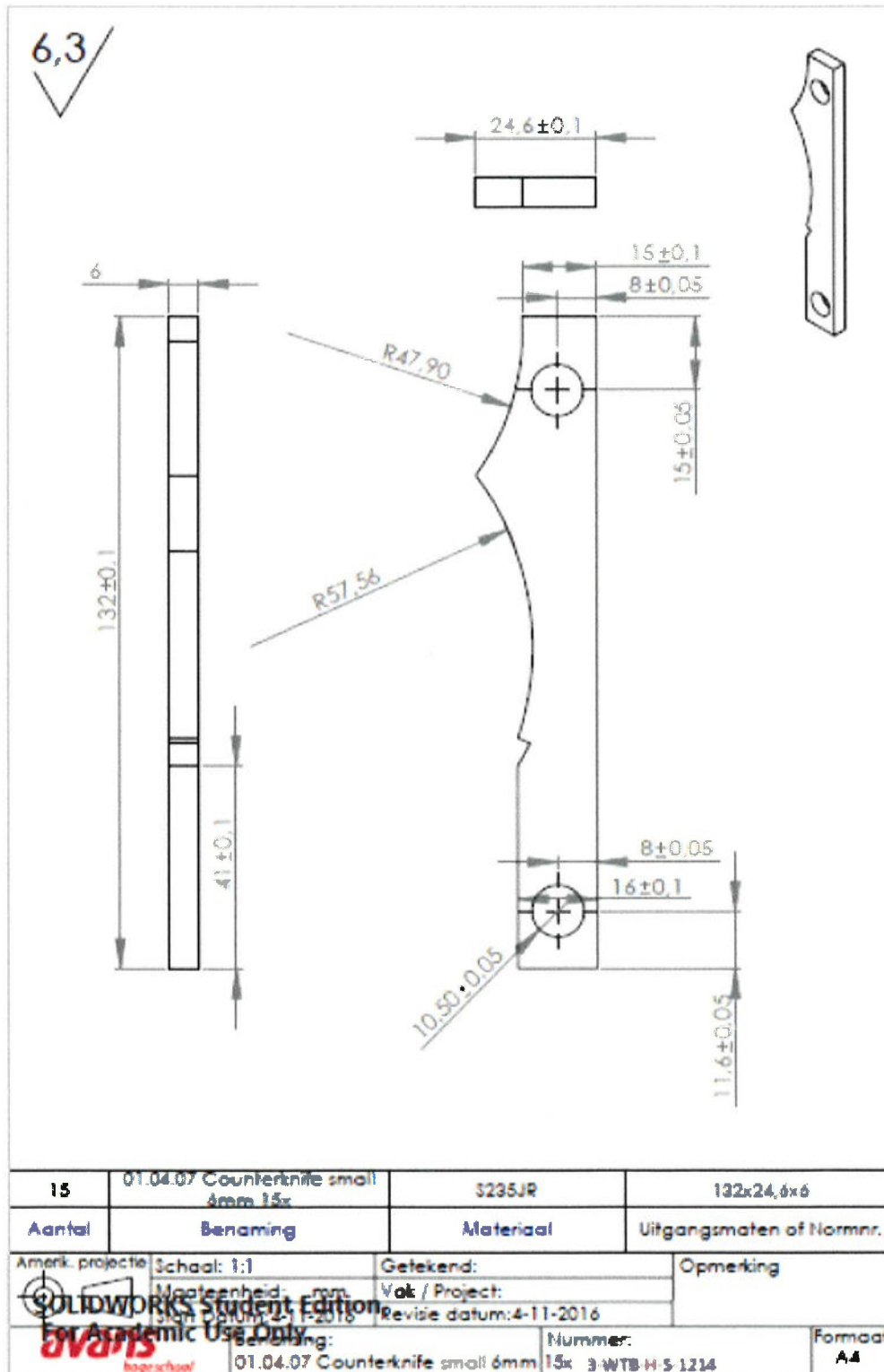


4	01.04.05 knife 4x	S235JR	
Aantal	Benaming	Materiaal	Uitgangsmaten of Normnr.
Amerk. projectie	Schaal: 1:1	Getekend:	Opmerking
	Maateenheid: mm	Vak / Project:	
	Revisie datum: 5-11-2016		
	Benaming: 01.04.05 knife 4x	Nummer: 3-WTB-H-S-1217	Formaat: A4

*R*

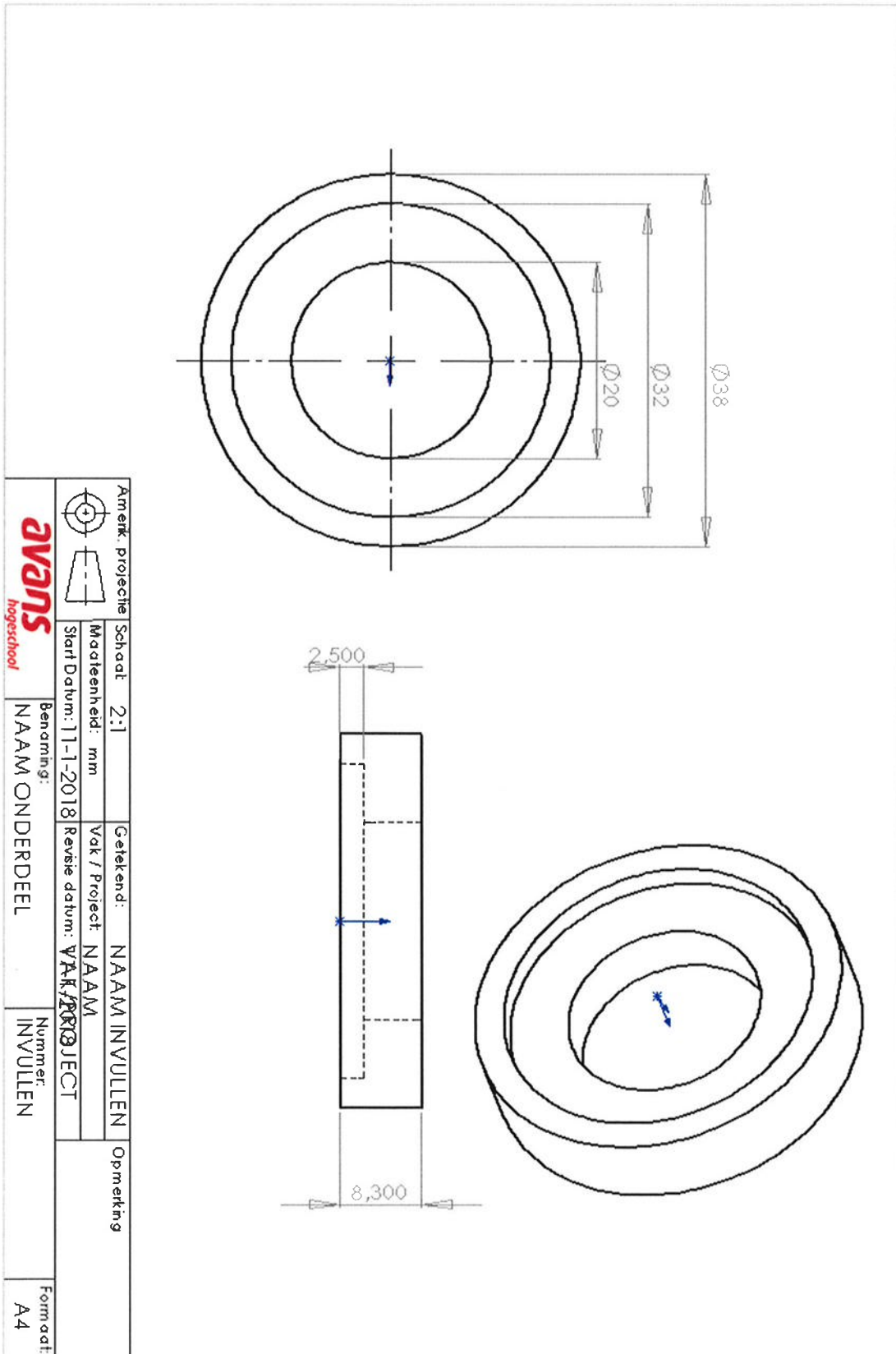
**Counterknife small.**

Hiervan hebben we er 15 nodig. Duurzame plaatindeling!

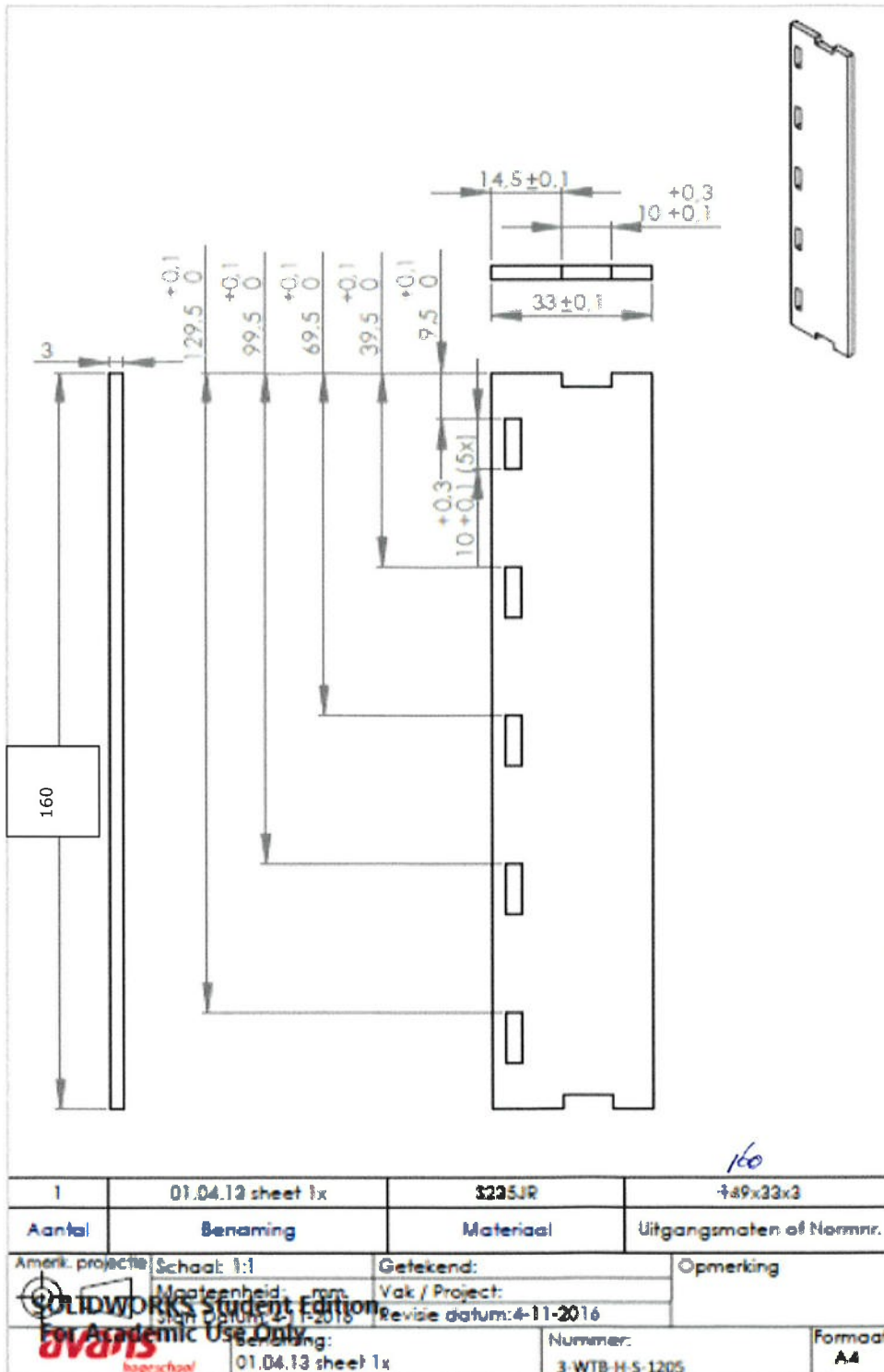


*g*

Vulring tussen lager en messen.



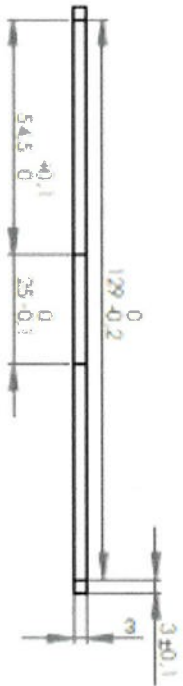
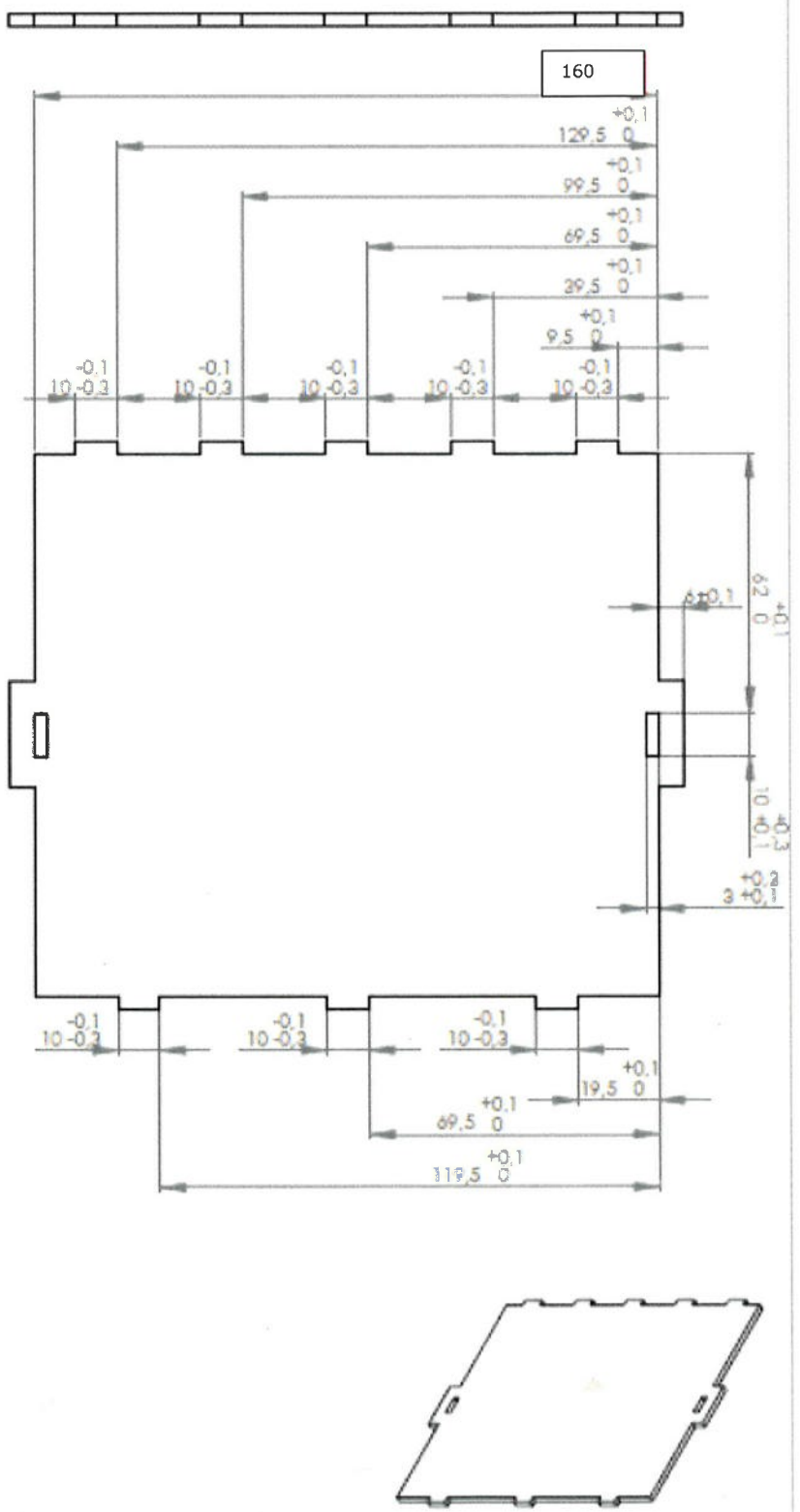
Onderdelen 3 mm



*g*



6.3



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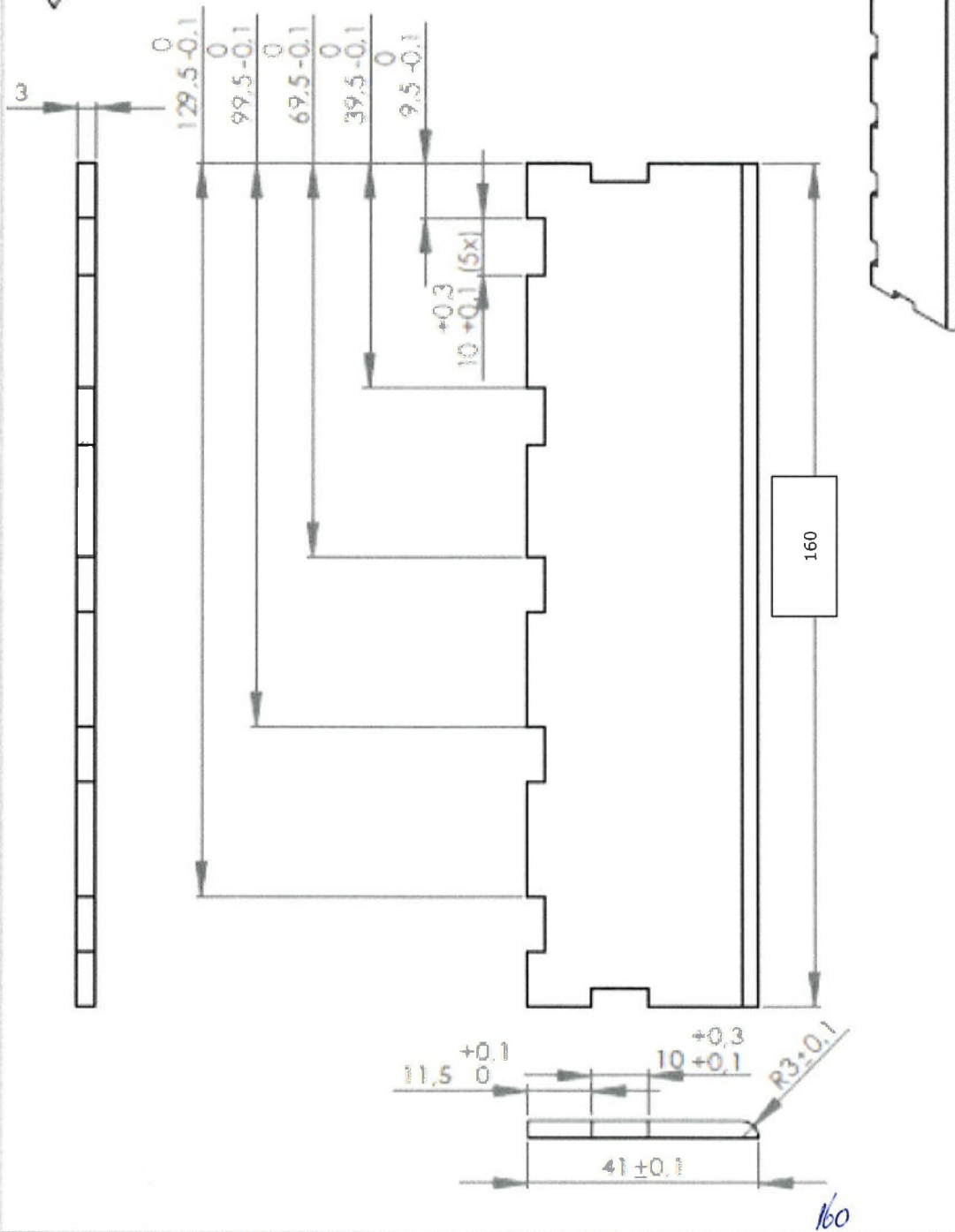
2	01.04.15	15x12x1.2	2x
Acetel	Separator	Material	1.35x1.2x1.2
Amount: Projected (Sheet 17)	Amount: Hand man	Material	1.35x1.2x1.2
Sheet: Datum: 3.11.2016	Sheet: Datum: 4.11.2016	Material	1.35x1.2x1.2
Version: 01.04.15	Version: 01.04.15	Material	1.35x1.2x1.2
Author: 3-INTS-45-1241	Author: 3-INTS-45-1241	Material	1.35x1.2x1.2
Checked: A3	Checked: A3	Material	1.35x1.2x1.2

15x12

*A*



6,3



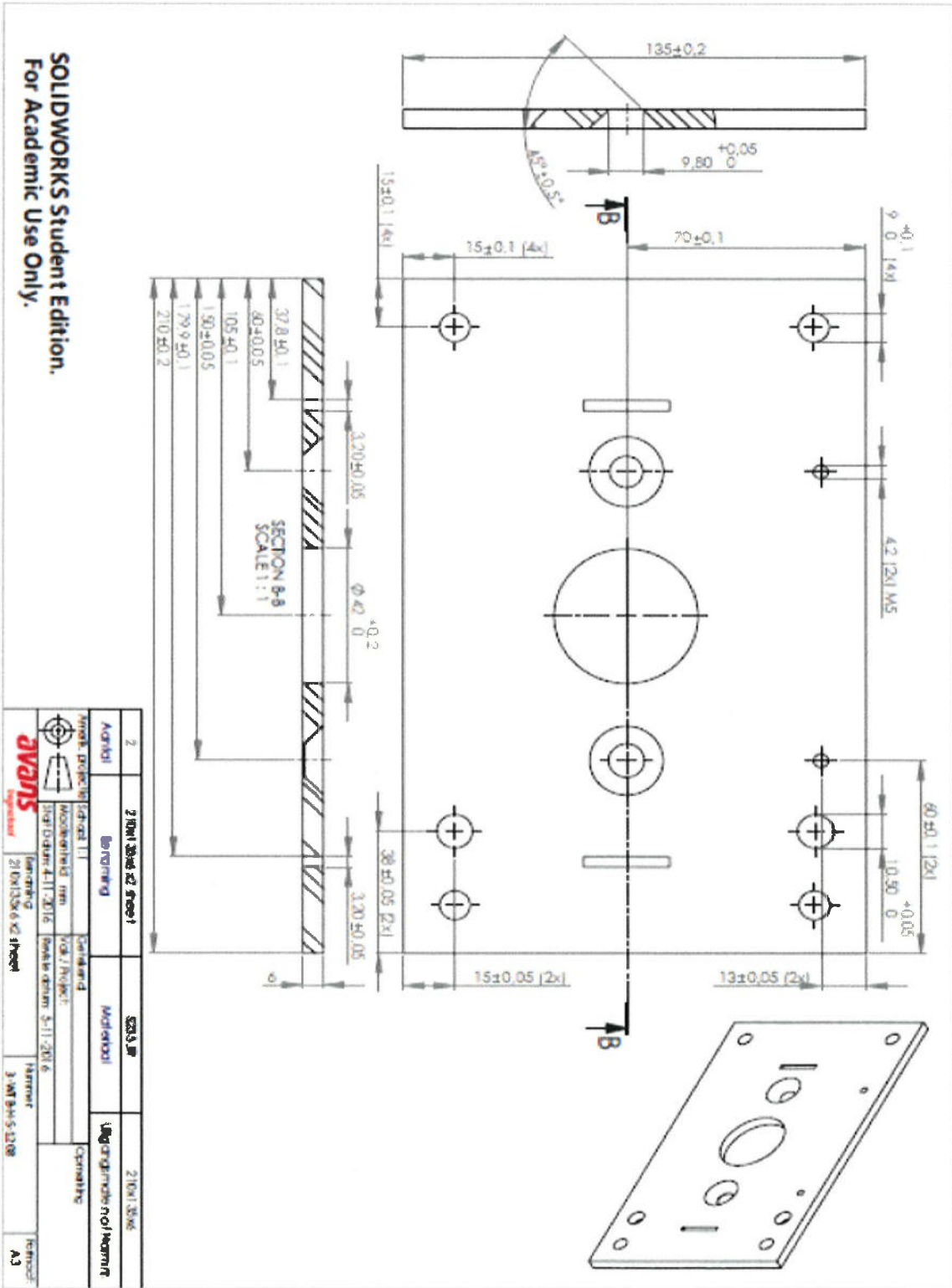
1	01.04.18 sheet	S235JR	149x41x2
Aantal	Benaming	Materiaal	Uitgangsmaten of Normnr.
Amerik. projectie	Schaal: 1:1	Getekend:	Opmerking
Maateenheid: mm		Vak / Project:	
Scherflijning: 2-1-2018		Revisie datum: 4-11-2016	
Scherflijning: 01.04.18 sheet		Nummer: 3-WTB H-S-1207	Formaat: A4

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bepeschwal

*gr*

Kopplaten 6mm.

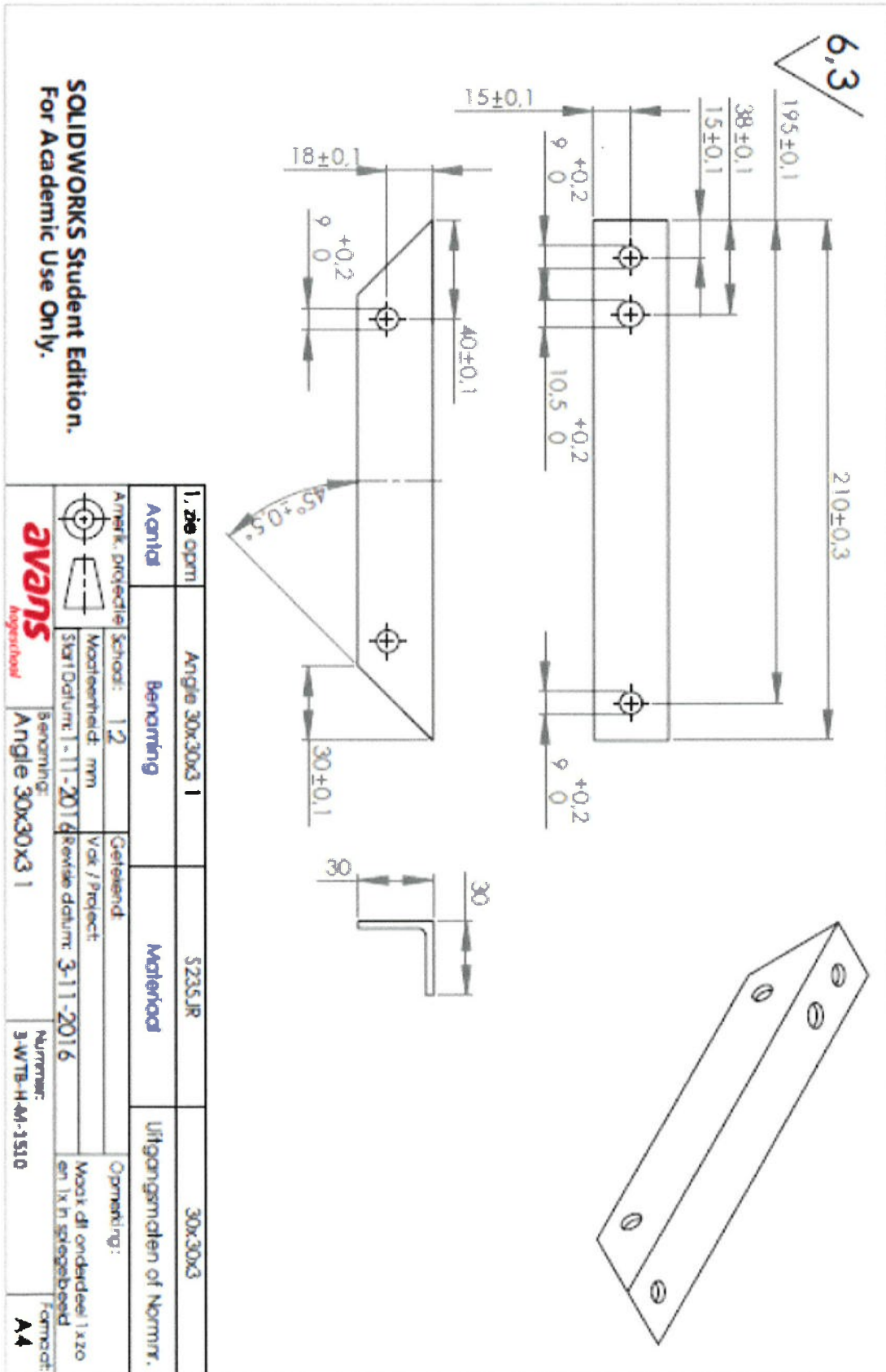
1x links en 1x rechts



*Handwritten signature*

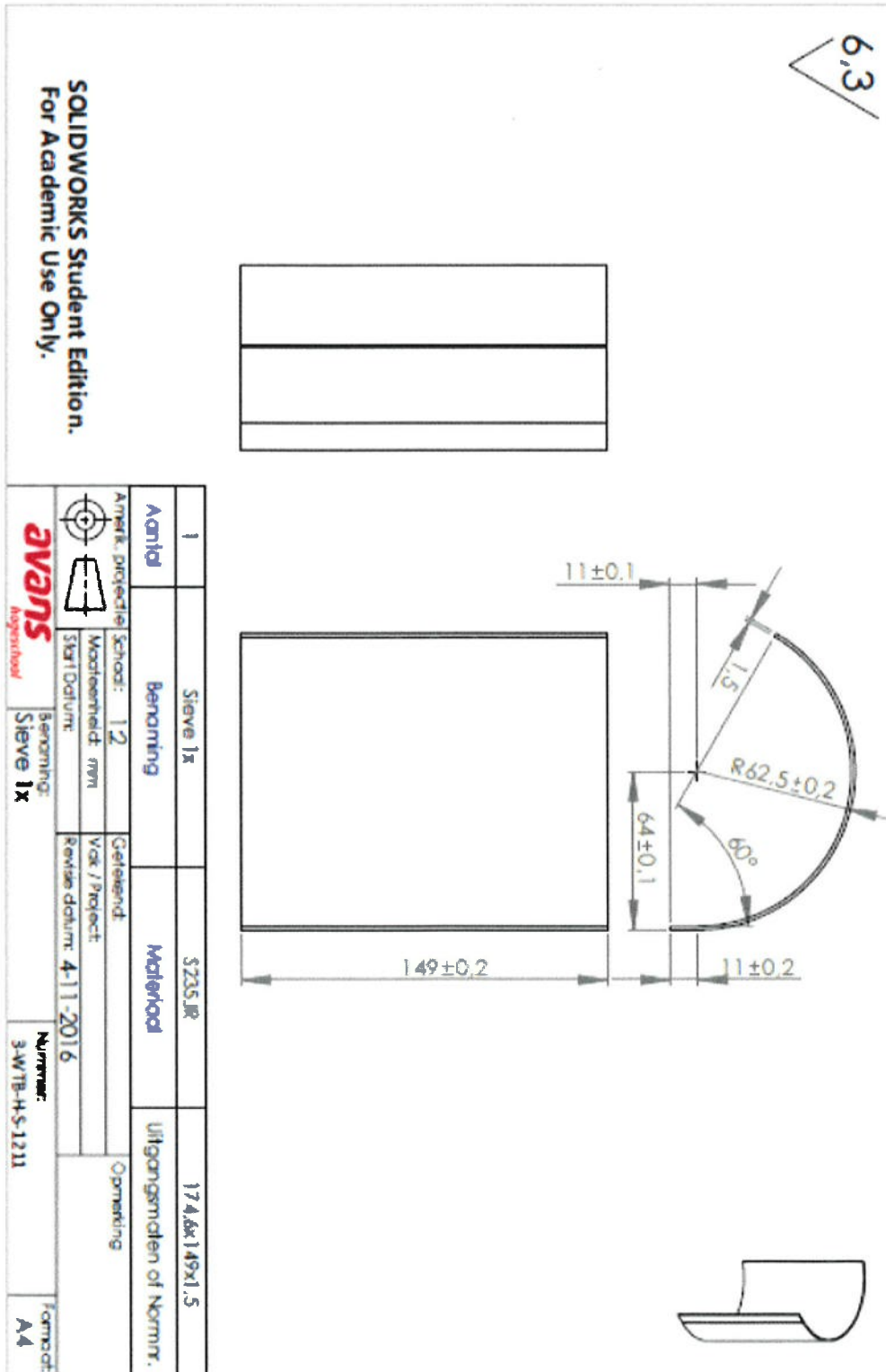
**Hoek t.b.v. bevestiging shredder aan frame.**

Dit onderdeel dient handmatig vervaardigt te worden.

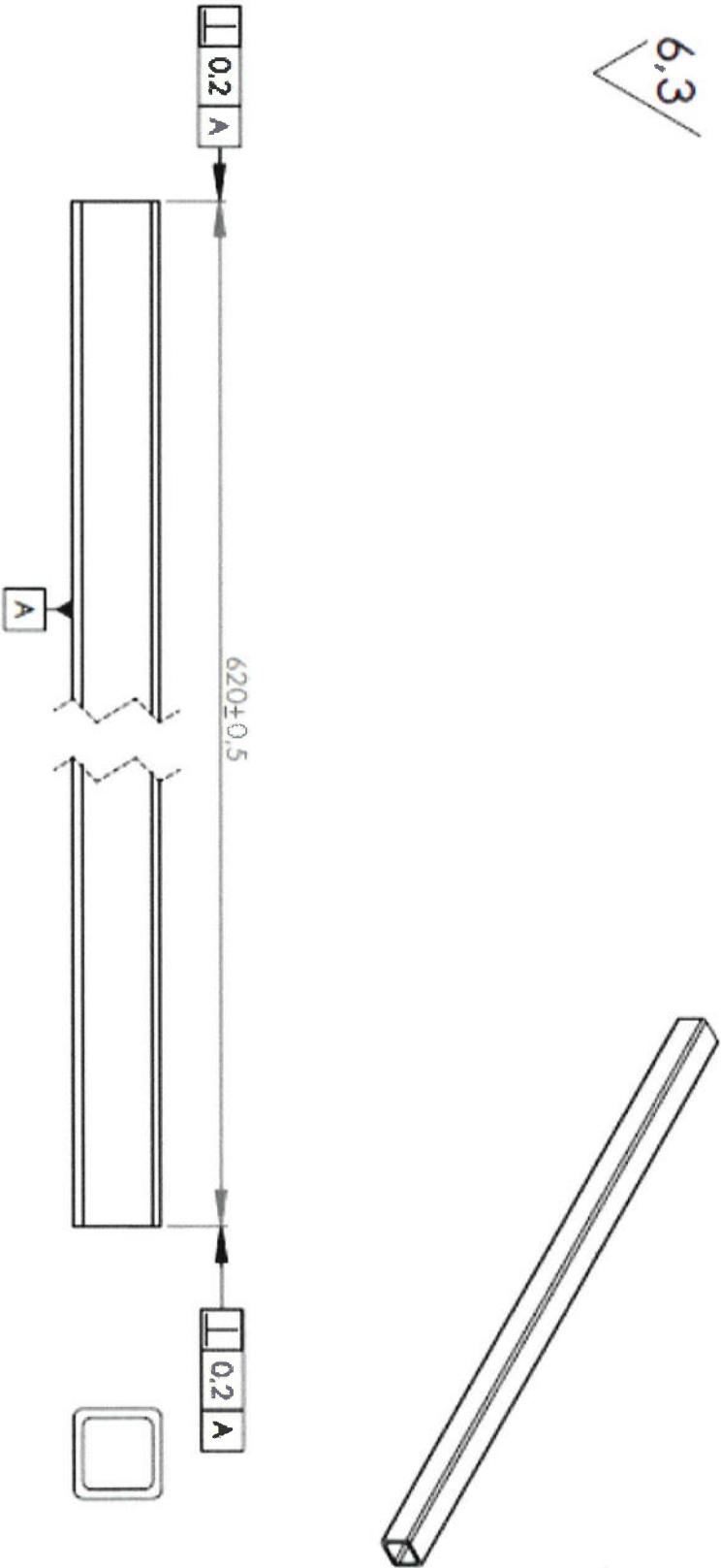


## Zeef

De zeef maken we 1 maal met een kleine of 1 maal met een grotere gatdiameter.



6.3



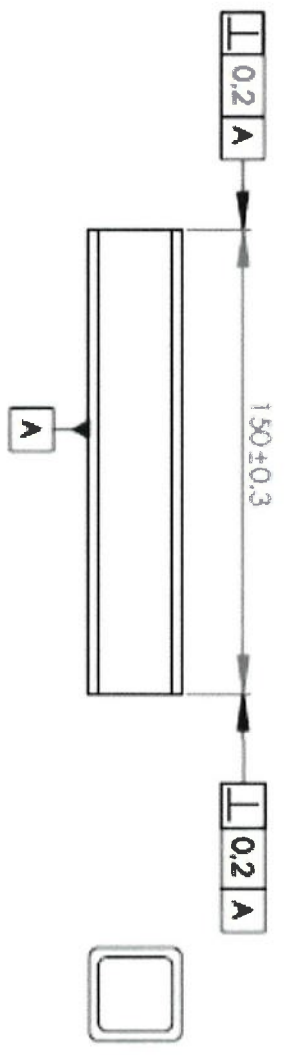
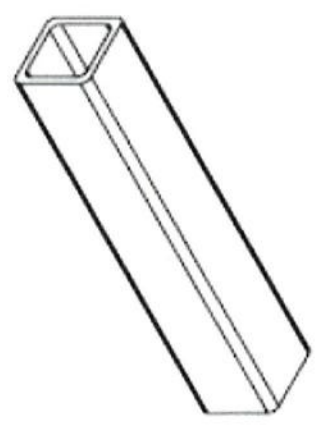
4	Leg 620 30x30x3 (2) (2) 4x	S235JR	30x30x3
Aantal	Benoeming	Materiaal	Uitgangsmaten of Normnr.
Amerik. projectie:	School: 12	Getalend:	Opmerking
Maatleenhed: mm	Start datum: 25-10-20	Vak / Project:	
Stop datum: 25-10-20	Bevrie datum: 25-10-2016		
Benoeming: Leg 620 30x30x3 (2) (2) 4x		Nummer: 3-WTB-H.M-1500	Formaat: A4



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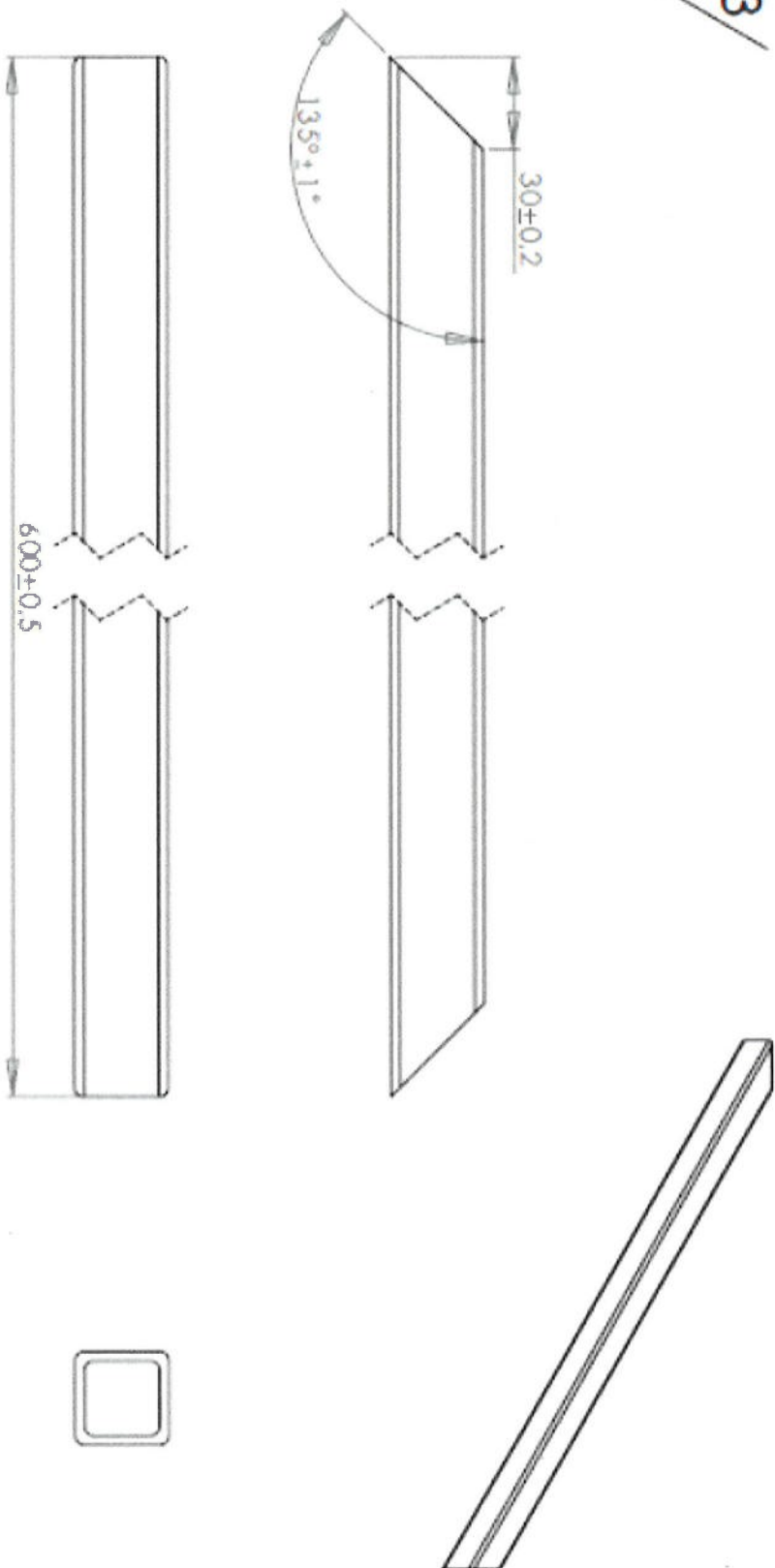


1	Leg 620 30x30x3 (2) (2) 4x	S235JR	30x30x3
<b>Aandl</b>	<b>Benoeming</b>	<b>Materiaal</b>	<b>Liggingssymbool of Normnr.</b>
Amerk. projectie: 	Schaal: 1:2	Getalend:	Opmerking
Maatleenheid: mm	Start datum: 25-10-20	Vak / project:	
Stop datum: 25-10-20	Revisie datum: 25-10-2016		
Benoeming: <b>150 30x30x3 2x</b>		Nummer: <b>3-WTE-H-M-1502</b>	Formaat: <b>A4</b>

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6.3



1	tube 600 30x30x3 (1) 2x	S235JR	30x30x3
<b>Aortid</b>	<b>Benaming</b>	<b>Materiaal</b>	<b>Uitgangsmaten of Normnr.</b>
Amerk. projectie:	Schaal: 1:2	Getalend:	Opmerking
Maatleerheid:	mm	Vol. / Project:	
Startdatum: 25-10-2016	Revisie datum: 2-11-2016		
			
		Benaming:	Nummer:
tube 600 30x30x3 (1) 2x		3-WTB-H-M-1506	Formaat:
			A4

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