I-LOCKERS

Additive Manufacturing Utilized for Prototype Parts

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ABSTRACT

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Additive Manufacturing Utilized for Prototype Parts

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The purpose of this thesis was to provide more knowledge to the readers about the different methods in additive manufacturing and how it can help a company to provide fast prototypes. The specific aim for this thesis was to manufacture prototypes which can be fitted onto the i-Lockers as functional concepts of what would later be made in a durable material. And hopefully be the basic for more products of the same nature.

The theoretical background was gathered from multiple sources that can be found in the references at the back of this thesis. Data required for the design of the prototypes was measured in the laboratory of TAMK, where the project was being designed with fellow students. Most of the design of the functional prototypes was also done in the laboratory. Printing of the prototypes was done with the available printers at TAMK. After printing all parts, the parts were fitted onto the project.

It was found that most of the printing would be done on a Prenta Duo XL printer since these were the best printers publicly available with the best properties for this thesis. Including dimension, ease-of-use, strength, materials, accuracy, etc.

Many parts were fitted and there are big improvements on the state of the project. But many more will need to be done before it is complete and can be delivered and fitted.

CONTENTS

GLOSSARY

TAMK	Tampereen Ammattikorkeakoulu (Tampere University of Applied Siences)
PLC	Programmable Logic Controller
RP	Rapid Prototyping
CNC	Computer Numerical Control
3D	Three Dimensional
STL	Stereolithography
CAD	Computer Aided Design
CADD	Computer Aided Design and Drafting
CAM	Computer Aided Manufacturing
FDM	Fused Deposition Modelling
SL	Stereolithography
LOM	Laminated Object Manufacturing
SLS	Selective Laser Sintering
EBM	Electron Beam Melting
LENS	Laser Engineered Net Shaping
3DP	Three-Dimensional Printing
MEP	Mechanical, Electrical and Plumbing
UV	Ultra-Violet
kV	kilo-Volts
BAM	Bio-Additive Manufacturing
PLA	PolyLactic Acid

1 INTRODUCTION

i-Locker is an automated system for storaging purposes. The desire of this project, is to improve the current system of storaging. The purpose of this thesis is that it wants to enable students, with a PIN code, to withdraw their stored luggage. Everything should be automated and easy to use as most student will be using this on a daily basis. There are two rotating axles, both with a sprocket on either side. On these sprockets are matching chains which hold the lockers in place. Both sides are thus symmetrical identical to each other to avoid torqueing the lockers. The basic principle of this device uses the common concept of paternosters.

Figure 1 shows the basic concept of a paternoster.

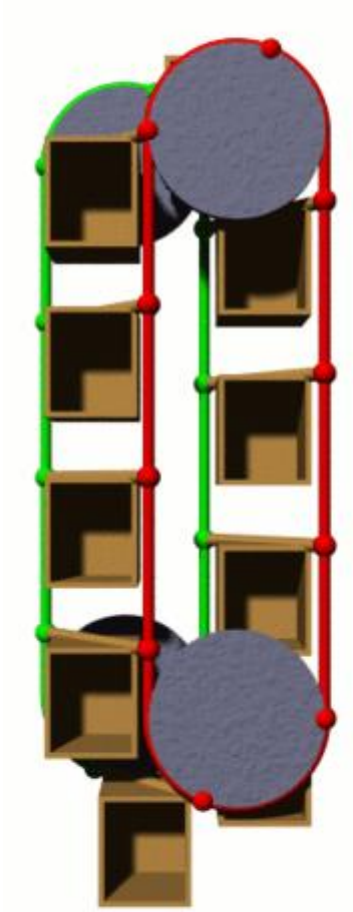


FIGURE 1. Basic schematic of a paternoster (RokerHRO, 2017)

The aim of the project is to create a functional automated storage system with integrated intelligence and accuracy. Accuracy is important since the lockers will not be individually secured with a code but by a hatch that will be automatically controlled through PLC technique. Thus, enabling the student to get their luggage delivered to them with the use of a simple PIN code. The system will remember the PIN when they deliver their stuff and lock the hatch. When the code is given to the system once again, it should remember which locker was linked to it, and remember the place of the locker so it can bring it to the hatchet. The hatchet is then unlocked and student will be able to get their belongings.

This thesis will be focused on; everything related to additive manufacturing, this includes the software part as well as the hardware used to make these methods viable. Everything that is needed to create fast prototypes through AM is also discussed. This thesis will also briefly show the most common advantages and disadvantages to AM methods and how to solve them. Also, how design work is done using CAD software, how files are converted and uploaded to the printer and what the difficulties are related to this.

First, a theoretical background is given as it introduces the methods that can be used for additive manufacturing, each given with their most common advantage and disadvantages. Then the project is introduced and what the aims are. After that the actual work is discussed, divided in different sections, including design, manufacturing and fitting of the prototypes. As last the thesis is summarized and discussed.

2 THEORETICAL BACKGROUND

2.1 Rapid prototyping

Rapid prototyping starts with a person and an idea, this person has something in my mind that would be profitable if successfully designed and manufactured. Through the processes of additive manufacturing, rapid prototyping has been simplified and attainable for everyone.

This method is used in all industries, it consists of constructing the desired product for evaluation. This way the prototype can be tested before manufacturing it at large scale. Out of these test, conclusions can be drawn about how to improve the design and wanted features. Repeating this procedure will give more insight on overseen faults and will provide us the information that we need.

Through this process, assurance can be granted that the final product is what it should become before it goes into manufacturing and sale on large scale.
Figure 2 shows how products get to their definitive version:

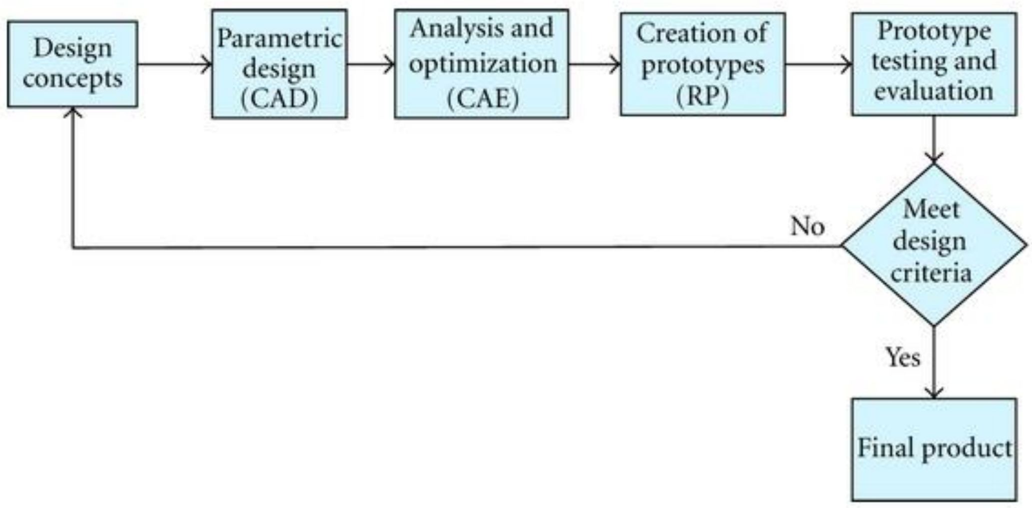


FIGURE 2. Product development cycle (Noorani, 2006)

Now, rapid prototyping is not only used for creating models. With the advantages in plastic materials, they can create finished products. But it is mainly for creating prototypes (Cooper, 2001).

Before 3D printing existed, one of the processes to do this, was called CNC, computer numeric control. This thesis will not focus on CNC but rather on 3D printing.
Today, these processes have other names like 3D printing, but they all originate from rapid prototyping (Noorani, 2006) (Kochan, 1997).

According to Wohler's report 2011 the growth rate for 2010 was 24.1%. The compound annual growth rate for the industry's history, until 2010, is 26.2% (Wohlers, 2011) (Wohlers, 2012).
This growth is shown in Figure 3.

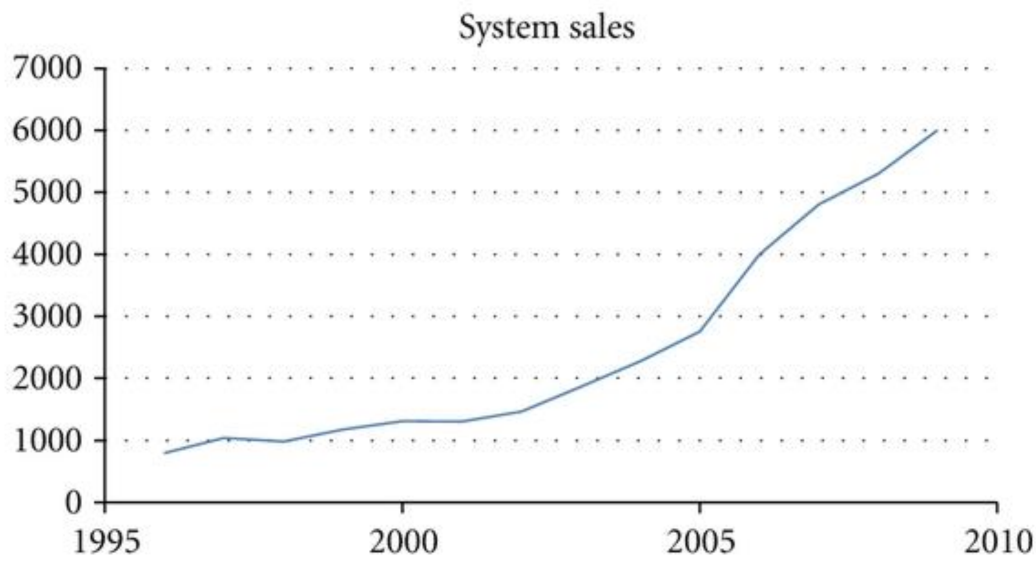


FIGURE 3. Growth of rapid prototyping (Wohlers, 2010). Adapted from (Grimm, 2004)

The only reason why rapid prototyping is possible is because other technologies have advanced. Software allows anyone to draw CAD (computer-aided design) files. Also because hardware and software controls the machines, CAM (computer-aided manufacturing). And because of machines like CNC (computer numerical control). These 3 technologies together have made it possible to print three-dimensional objects (Noorani, 2006) (Cooper, 2001) (Kruth, 1991).

Rapid prototyping is not always the best solution, since the dimensions of the available printers are usually not big enough for some parts. These may have to be produced in the CNC. Also, material selection would be a weak point. It's possible to print in metal and ceramics but some commonly used materials might not be possible (Kruth, 1991).

2.2 CAD

CAD, or computer-aided design and drafting (CADD), is the use of computer technology for design and design documentation. CAD software replaces manual drafting with an automated process.

A common place for the use of 3D or 3D CAD programs is in the field of architecture, MEP (Mechanical, Electrical and Plumbing), or structural engineering. These programs can help anyone explore design ideas, visualize concepts through photorealistic renderings, and simulate how a design will perform in the real world. This includes strength testing, aerodynamics, assembly, ...

CAD programs have different features depending on whether the design process involves 2D vector-based graphics or 3D modelling of solid surfaces. Most 3D CAD programs allow the user to apply multiple light sources, rotate object in three dimensions, and render designs from any angle (AutoDesk, 2017).

Figure 4 shows an example of 3D model rendered in SolidWorks, the program used at TAMK. There are many different CAD programs.

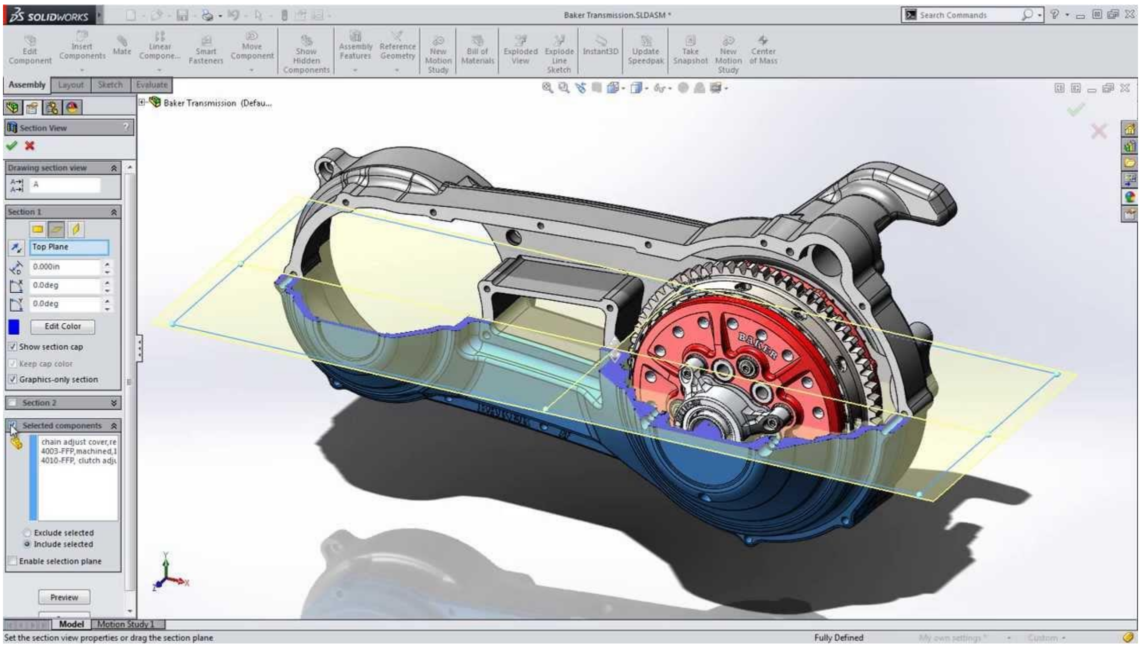


FIGURE 4. Example of CAD in SolidWorks (Martin, 2015)

2.3 STL file

First, through CAD software, an accurate representation of the desired model should be sketched and extruded until the final state is satisfying the needs that are pre-measured and discussed before designing.

This 3D CAD file is converted through complicated algorithms. First, every layer is sliced through the z axis, creating slices that can be converted into triangles and lines. This process is repeated for every layer until a final mathematical file is created which can be read and used by the desired printer (Noorani, 2006) (J. W. Halloran, 2011) (C. Iancu, 2010).

There are multiple programs for finishing touches, where the desired part can be rescaled and fitted in the easiest position for the printer. This program allows the user to make smaller prototypes than the end product to test or show in eventual presentations. One of these programs, used at TAMK in Tampere is called Simplify3D.

Figure 5 shows the chart in which order the computer converts files from CAD to STL.

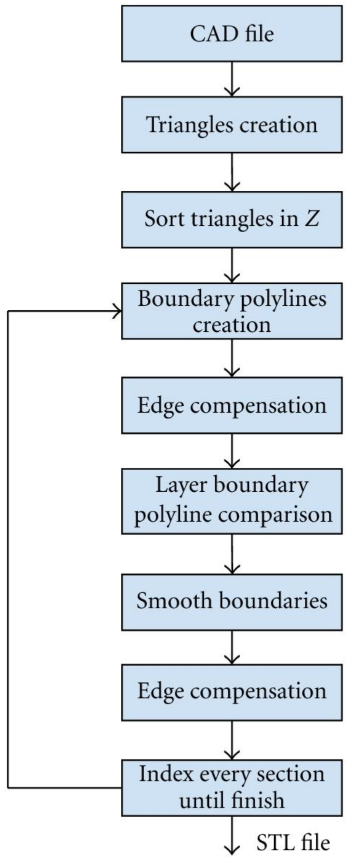


FIGURE 5. Conversion chart from CAD to STL file (Noorani, 2006)

2.4 Additive manufacturing

In additive manufacturing, a computer is used to design a CAD (computer-aided design) file which we convert into a STL (stereolithography) file. By doing this, the design made in the CAD file is approximated by slices and triangles that contains the data of each slice that is going to be printed. Through dedicated software, data can be uploaded to the printer which will print layer by layer until the end product that we designed is accomplished.

By additive manufacturing processes, there is the possibility to create lighter structures and therefor reduce weight. Which is attractive to high end industries like aerospace.
It also helps us to find new boundaries, for example for the use in medical applications. Which helps the patients and physicians. Fixtures can be created for use in the operating rooms, or custom-made implants, surgical tools, …

Huge progress is being made on the capabilities of additive manufacturing but there is also still a long way to go. Through a lot of research there will be even further accomplishments and developments. Also, by the price drops in 3D printing technologies, which makes it more attainable for the consumers, there will be a lot of breakthroughs in the next years. Open platforms are known for this and because of that, the quality of the 3D printers will still improve at an increasing rate. Through additive manufacturing methods, many previously ideas that would never be tried, can now be tried for a low cost.
With these new methods coming to every market, many people outside the industry have started developing products that seem to interest a whole new community.
There are online sites helping people to sell their STL files so this will help people get motivated to design and test their own ideas.

As seen in the last couple of years, many schools have starting using 3D printers since it is obvious that the future of manufacturing will depend on additive manufacturing. It is easier to use with the right education, less waste, less space required, cheaper than other manufacturing options, …
There is certainty that the accuracy can still improve because very intricate details are still a challenging thing to print. Also, the speed is one of the weakest points.

2.5 Benefits of Additive Manufacturing

There are a lot of benefits to these methods when compared to traditional manufacturing methods. Listed below are some advantages:

1. Part Consolidation: This is the most important benefit, it enables industries to create parts with less smaller parts, thus creating a product that is less subject to wear and tear, stress and weak points. This also creates smaller manufacturing times, thus lowering the need for tools and reducing personnel costs (Wohler, 2014).
2. Light weighting: As result of the previous benefit, it creates a part with less bolts and screws. In doing so it reduces the weight of the final product (Wohler, 2014) (Sachin Nimbalkar, 2014).
3. Reduced time to market: As less time is needed for assembly, more complex parts can be produced in shorter time frames (Energy, 2012).
4. Demand adjusting: There is no need for excess fabrication and storing as parts can be made on demand and exactly as many as needed. There is no need to change a whole production line in order to make one part (Energy, 2012).
5. Less waste: Because the parts are build layer on layer, there is no useless material thrown away and reduces the footprint of manufacturing compared to traditional manufacturing method. In comparison, it can reduce the material needs and costs up to 90% (Economist, 2011). Also, human errors in production lines are reduced so there are less faults and thus less waste by mistakes (Petrovic, 2011) (Sachin Nimbalkar, 2014).
6. Reliability: As discussed by the previous point, a higher quality can be assured, which guarantees more reliability towards customers because there are less human errors (Petrovic, 2011) (Sachin Nimbalkar, 2014).

2.6 Methods of Additive Manufacturing

Figure 6 shows a diagram with the processes that this thesis will discuss. The processes considered are stereolithography (SL), Polyjet, fused deposition modeling (FDM), laminated object manufacturing (LOM), 3D printing (3DP), Prometal, selective laser sintering (SLS), laminated engineered net shaping (LENS), and electron beam melting (EBM).

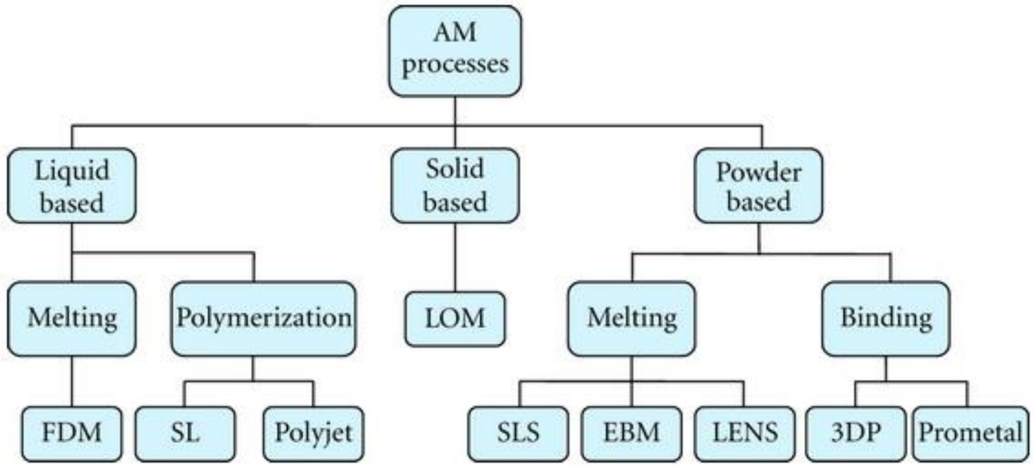


FIGURE 6. 3D printing processes. Adapted from (Kruth, 1991)

During a survey created by Wohler, companies asked more than 5000 customers what they used 3D printing for. Figure 7 shows the chart that shows the conclusions of these surveys.

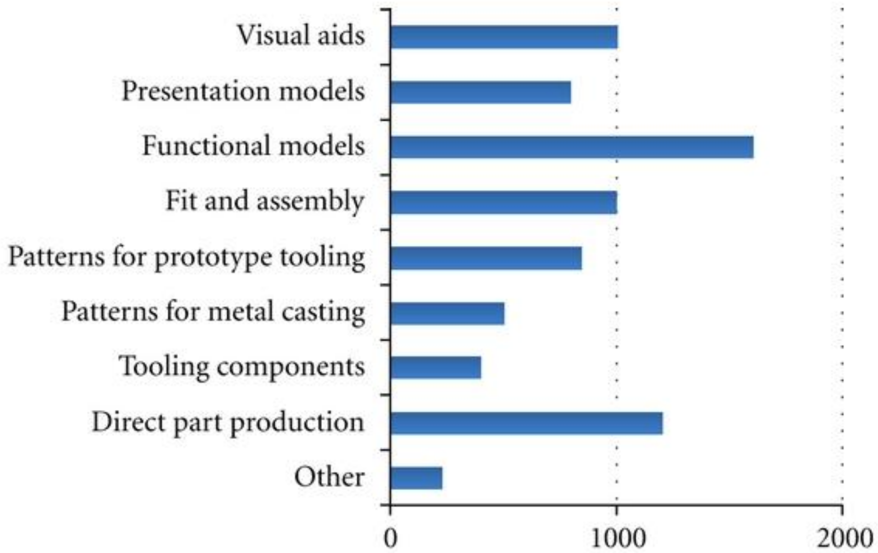


FIGURE 7. Field of use of 3D printing (Wohlers, 2009)

As for this thesis, it will adress multiple fields. Presentation models are going to be this thesis's main field but will also include functional models that can be printed in metal if desired. In this thesis the fitting and assembling of parts will also be done.

2.6.1 Fused Deposition Modelling

FDM is a layer additive manufacturing process that uses production grade thermoplastic materials to produce both prototypes and end use parts. This technology is known to accurately produce featured details and has an excellent strength-to-weight ratio.
The process of FDM is mainly used for the build of concept models, manufacturing aids, low volume end use parts and functional prototypes.

The process begins by slicing 3D CAD data into layers. The data is then transferred to a machine which constructs the part layer by layer upon a build platform. Thin material lines on spools are used to construct each layer of the part. There is a spool for both the thermoplastic material and support material. Uncoiled material is slowly extruded through dual heated nozzles. Then the extrusion nozzle precisely lays down both support and thermoplastic material on the preceding layers. The extrusion nozzle moves along a horizontal x-y-plane. While the build platform moves on the z-axis, making it possible to construct a 3D print. The finished part can then be removed from the build platform and can then be cleaned o its support material. Raw FDM parts have visible layer lines. However, most of the fabricators offer multiple finishing options to create smooth, even-surfaced parts. Including hand-sanding, assembling and painting (Iwan Zeina, 2002).

Since FDM parts are constructed with production grade thermoplastics, including ABS, polycarbonate, … they are both functional and durable. FDM is used in a number of industries, including aerospace, automotive, industrial, commercial and medical (Samar Jyoti Kalita, 2003). This process is more cost effective since there is no resin to cure, no chemical process post-processing required and the machine itself is less expensive (Noorani, 2006) (Cooper, 2001).

Figure 8 shows the principles of the FDM machine. It shows the build platform that moves in the z axis and where the material is extruded. Two spools can be seen, one for the support material and one for the build material. This material is then guided through the shown liquifier head.

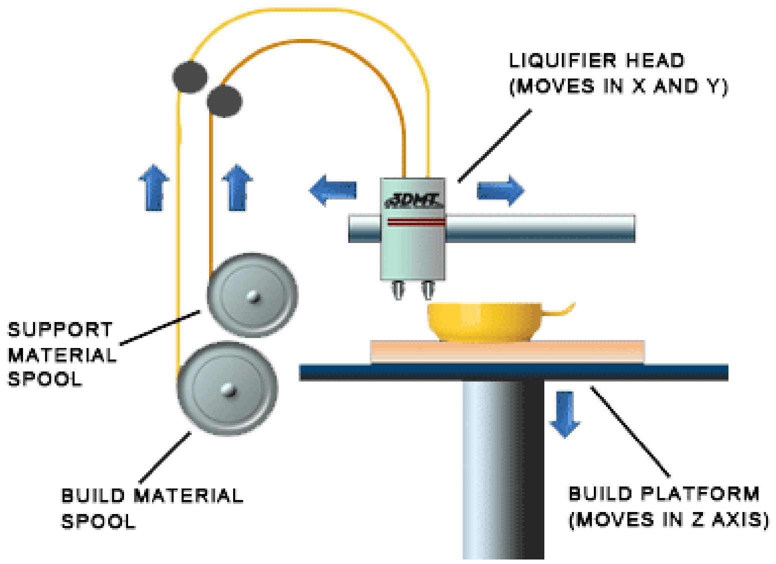


FIGURE 8. Schematic build of a FDM machine

2.6.2 Stereolithography

Stereolithography is a liquid based process. In the same way, the other processes create products we first start with a CAD file that is converted to a STL file. Each layer is printed through solidification of a photosensitive polymer. This happens when an ultraviolet laser makes contact with the resin. The quality and thus thickness of the layers depends a lot on the used equipment but are mainly much better than a machine that uses extrusion. Because the material is chemically fixed to each other, the achieved results have a much higher strength and definition. Layer thickness can be achieved of less than 10 μm. When the product is finished, the excess resin can be reused (Noorani, 2006) (Cooper, 2001) (Kruth, 1991).

The basics principle of this process is called ultraviolet curing. Ultraviolet curing is the photochemical reaction that generates crosslinks in liquid based polymers and therefor creates a solid layer (K. Studera, 2005).

The platform goes down (or up, depending on the machine) everytime a layer is cured, so there is place for new, fresh resin to flow onto the already cured layer. Thus a new layer can be cured on top of it.

Figure 9 shows the basic schematic build of an SL machine. Again a platform can be seen in the basin of liquid polymer that moves on the z axis. Also the laser and mirror for the actual solidification can be seen.

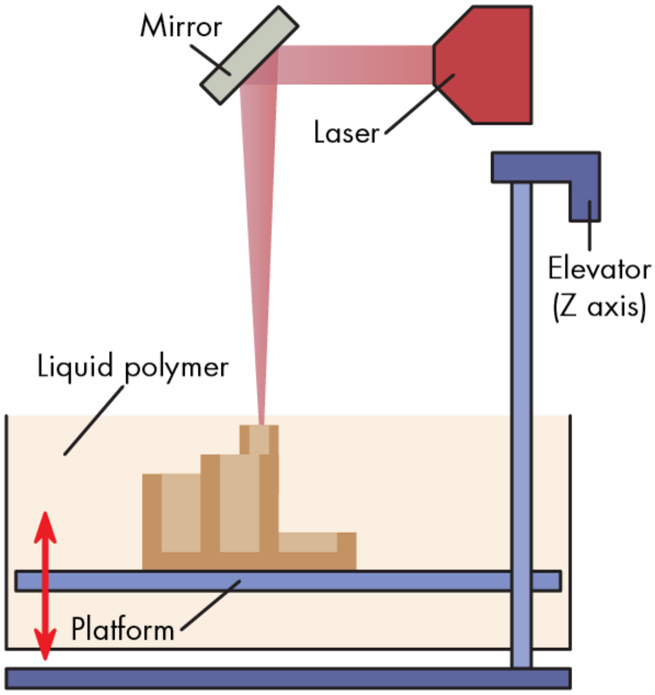


FIGURE 9. Schematic build of a SL machine (Kerns, 2015)

Another possibility is to disperse ceramic powder within an ultraviolet-cureable solution. The basic principle of manufacturing remains the same (Michelle L. Griffith, 1996) (D. T. Pham, 2000).

Some negative points of the lesser expensive equipment used for this process is:

- over curing, which causes overhang in places where there is no bottom layer for support;
- lines caused by scanning the desired product;
- finishing touches to the product, aka finishing, must be done by hand.

This occurs far less with more expensive and high-quality equipment (H. Kim, 2010).

There is the possibility to print one product in various kinds of material. This is a lot of work though. First this must be scheduled in the software. Every time a new layer is reached that should be printed in another material, the machine must be stopped, drained of the previous resin, and filled with the new desired resin. Even when the first resin is desired again later, this process should be repeated (M. Szilvœi-Nagy, 2003).

2.6.3 Polyjet

Polyjet is also a layer additive manufacturing method. It is used to develop plastic prototypes from 3D CAD data. This RP process uses inkjet technology, also seen in common printers, combined with UV curable materials to quickly and cost-efficiently produce highly detailed and accurate physical prototypes. Polyjet is one of the fastest prototyping processes available to develop high precision parts and is very ideal for smaller parts and master patterns.

The same process is used, it slices CAD data into STL files. Which is then send to the Polyjet machine. This machine then prints the object one layer at a time. Similar to how an inkjet printer lays down pigment, the Polyjet print technology lays ultraviolet curable material onto the platform. Eventually creating a cross section of the part. There is a UV light attached close to the nozzles, that cures the projected layer at as it is being printed. Once the cross section is complete, like other processes, the build platform moves down on the z-axis, creating space for a new layer to be printed.
At the same time the part is build, support material is added, to add strength to the product in the process of producing the product. Once the part is finished, it is removed from the platform and then cleaned or sanded by hand. The surface finish is quite good. It prints layers to an accuracy of 16 μm (P. Gay, 2015).

Figure 10 shows the schematic of a Polyjet machine. It shows the tanks with support and build material that are guided through the inkjet print heads onto the platform and solidified through the use of the UV curing lamp.

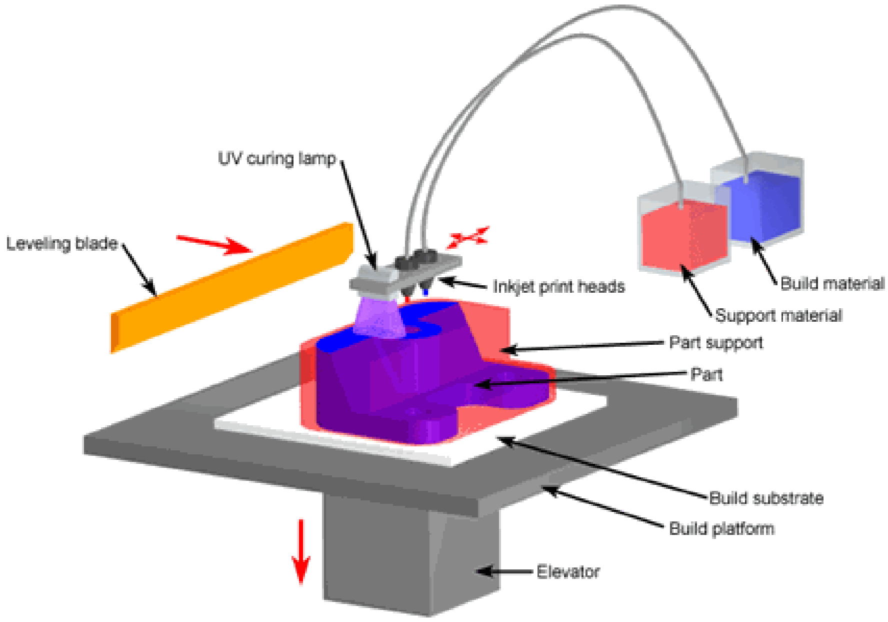


FIGURE 10. Schematic of a Polyjet machine (Naidu, 2017)

The only disadvantage to this technique is weaker parts than other similar processes (like SL and SLS).

Polyjet is available for many industries, including medical, entertainment, consumer product, automotive and industrial design.

Polyjet is one of the processes that makes it easier to print in a variety of colors (Wohlers, 2010) (Singh, 2011) (V. Petrovic, 2011).

2.6.4 Laminated Object Manufacturing

LOM is the only solid based process and therefor has major differences from the previous seen techniques.
Although it uses the same CAD and STL files to produce parts, there are many differences.

It uses sheet material that will be bonded together through heat and pressure. There are multiple rollers, two are big, containing the sheet material with thermal adhesive coating. One of these big rollers, contains fresh sheet material. The other one is for waste material, this roller ensures there is enough pressure so the sheet material stays flat across the platform where it is being cut. The other, smaller rollers, support the material as it is being guided across the platform.
A laser guided through an optical head, creates the shape designed in the CAD file.
As with previous seen techniques, the platform goes down each time a layer has been finished so there is room for new material. A heated roller is attached on top of the sheet material and moves along the freshly cut form so that this is bonded to the previously made layer (Noorani, 2006) (Cooper, 2001).

This process creates rapid prototypes for a relative low cost with no support structures required. The dimension of these parts can be very large, although complex internal cavities are very hard to build. There is no requirement for post-processing. This process can be done in a variety of materials, including papers, composited and metals.
There are also some downsides to this process since it creates a lot of waste and has a low surface definition (Singh, 2011).

Figure 11 shows a schematic build of a LOM machine. It shows the support rolls, heated roller and material rollers. The laser can be seen and is guided through a mirror and an X-Y moving optic head. Everything moves according the red arrows.

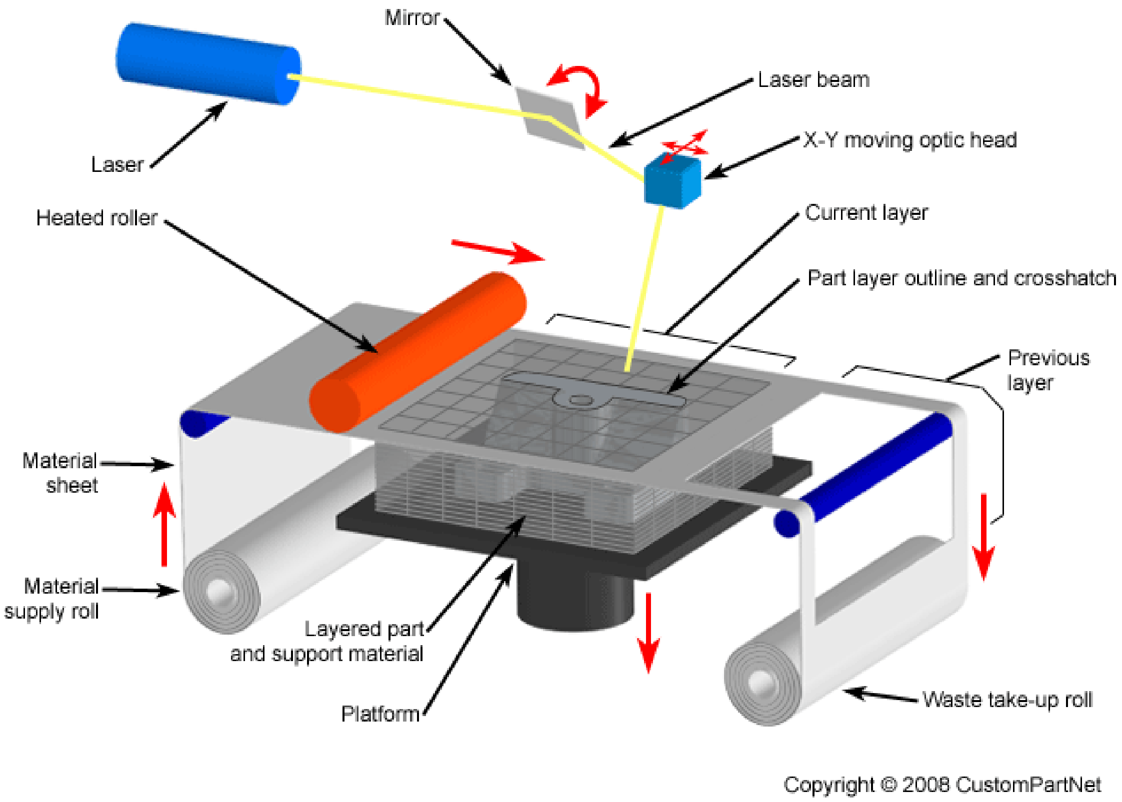


FIGURE 11. Schematic build of a LOM machine (CustomPartNet, 2008)

2.6.5 Selective Laser Sintering

As seen in previous techniques, it uses the same basic principles including CAD and STL files which are uploaded to the machine to process. This process is the first one discussed which is powder based. It uses powdered nylon 11 and nylon 12. Property enhancing fillers are added to create rugged SLS parts, suitable for a variety of prototype and production applications (T. Hwa-Hsing, 2011) (D. Slavko, 2010).

After a levelling roller spreads a thin layer of powdered material across the powder bed, a CO_2 laser traces the cross section of the material. As the laser scans the surface, the material is heated and fused together. Once a single layer is completed, the platform moves down, allowing the roller to spread a new layer of powdered material across the bed. In doing so, the roller takes excess material which can later be reused. This process is repeated, building layer upon layer, until the part is finished. As SLS parts are build, they are accompanied by uncentered powder, providing some added strength, which eliminates the need for support structures.

Parts produced are lightweight, highly durable and both heat and chemical resistant. This makes SLS an excellent choice for producing production parts without the expense of tooling. This process allows us to create complex structures. It is also a very accurate method since the size of the particles are the only limiting factor for this (Seung H Ko, 2007).

Many different materials can be used, including ceramics, metals, polymers and combinations of these (J. W. Halloran, 2011) (T. Hwa-Hsing, 2011) (G. V. Salmoria, 2011).

Typical uses for SLS include tools and fixtures, fuel tanks, flight rated components for unmanned aerial vehicles, automotive designs, airlocks, architectural models and artistic sculptures.

Figure 12 shows the schematic build of a SLS machine. The roller guides the powder from the powder delivery system onto the fabrication powder bed. The laser can be seen that is guided through a scanner system onto the powder bed, exactly where the part is going to be solidified.

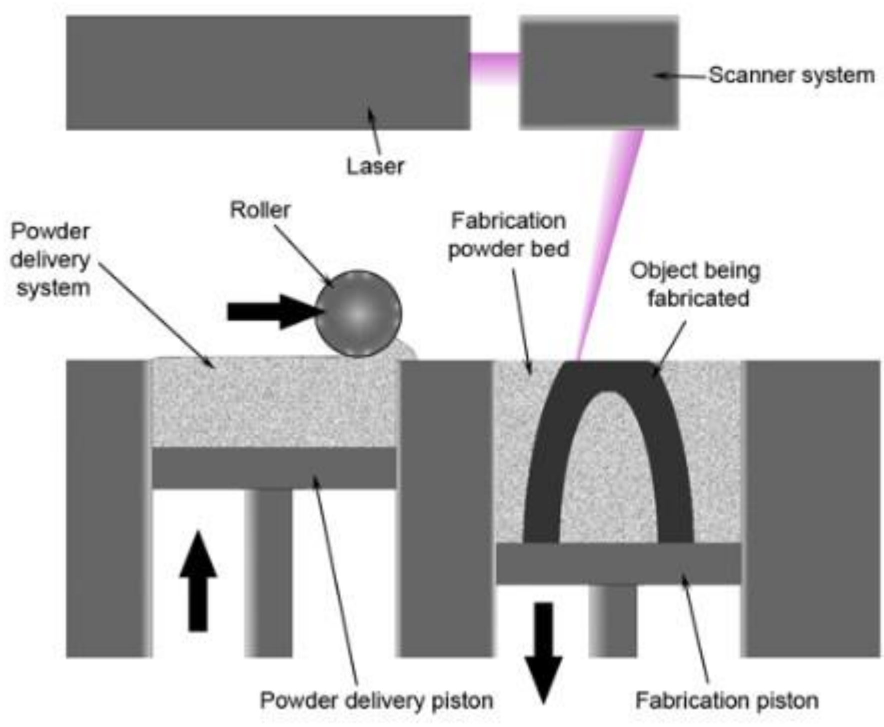


FIGURE 12. Schematic build of a SLS machine (Pros, 2014)

2.6.6 Electron Beam Melting

EBM is quite similar to SLS, as it is also powder based but uses an electron beam laser powered by high voltages from 30 to 60 kV. It is not as popular as the other techniques mentioned but is growing rapidly.

As SLS and other methods, it uses CAD and STL files to produce parts.
The method is practically the same as with SLS but happens in a vacuum chamber to avoid oxidation.

This process is only capable of constructing metal parts.
One of the main interests of EBM is manufacturing in space because this gives us the possibility to create complex designs with strong materials which will be needed in further space exploration (L. Murr, 2012) (Semetay, 2007).

Figure 13 shows a schematic build of an EBM machine. The electron beam column is guided through several lenses before it hits the powder bed, the build platform moves down when a layer is finished. This all takes place in a vacuum chamber. A rake makes sure the powder is levelled before creating a new layer.

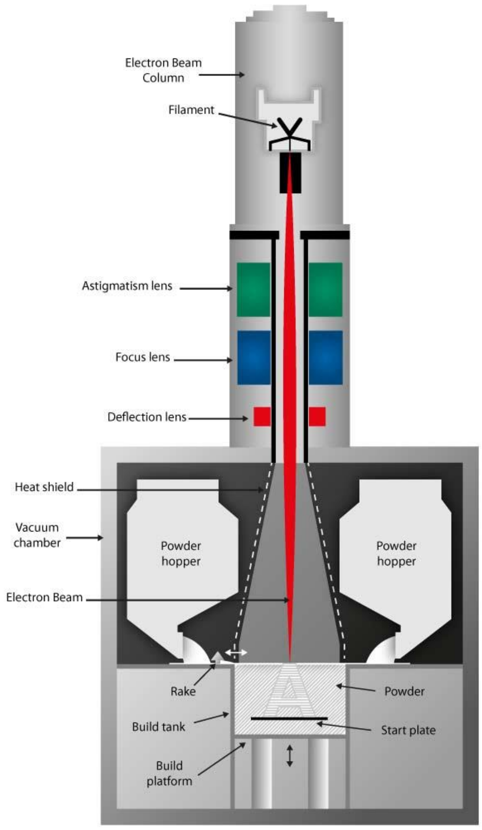


FIGURE 13. schematic build of an EBM machine (EBM, 2017)

2.6.7 Laser Engineered Net Shaping

LENS is an additive manufacturing process that uses metal powder sprayed into a laser to produce fully dense parts with a high deposition rate. The high-powered laser melts the particles together and when it cools down, it is solid (Cooper, 2001).

A 3D drawing of the part is made and sliced into an STL file which is uploaded to the machine. The powder used is placed in a dispenser, which ensures a constant flow during the projection. More than one type of powder can be used at the same time. Allowing the production of parts with chemical composition grade materials. The chamber of the system is filled with Argon, in order to obtain an atmosphere containing only a few ppm of oxygen. It is thus possible to work with reactive metals, such as titanium and niobium. In contrary to most previous seen techniques, the laser head does not move but the platform also does the x and y movements. The part is printed in a few hours. After a last step of surface machining, the final part is obtained (J. W. Halloran, 2011) (Xiong, 2009) (V. K. Balla, 2008).

Exclusive to this technique, it can also do part repair, production of surface gliding (providing a self-lubricating surface so there are only 2 parts needed for a bearing or glider) and adding new sections to an existing part.

This method allows the use of many different materials, including stainless steel, copper alloys, vanadium, aluminium and various combinations.

The only downside to this method is that there is a possibility for residual stress, because the heating and cooling could be uneven spread (Y. S. Liao, 2006).

Figure 14 shows the schematic build of a LENS machine. The high-powered laser is guided through a mirror and lens into a material deposition head where argon and powder is added. This is then sprayed onto the table. In contrary to the other platforms, it is the build platform that does the moving.

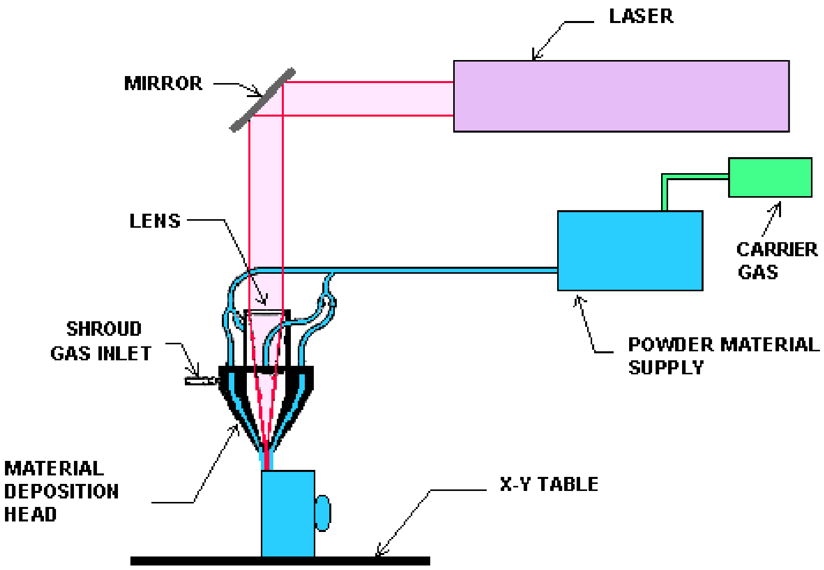


FIGURE 14. Schematic build of a LENS machine (Y. Xiong, 2009)

2.6.8 Three-Dimensional Printing

3DP is a process that allows us to create models with multiple colours as the colour depends on the applied binding material. In doing so, it creates very aesthetical pleasing models. This process is also powder based but uses a different technique called binding instead of melting (Cooper, 2001).

Again, the CAD file is converted to an STL file which will be uploaded to the printer. The roller of the printer spreads a layer of plaster powder over the build platform. The print head then moves across the layer, like a common printer, applying a layer of binder solution in the shape of the first layer sliced from the STL file. This layer of binder can be confused with normal ink. This binder solution binds the powder together in the desired shape. Just like with Selective Laser Sintering, excess powder, left unbound, acts like a support structure for the part. The build platform moves down a single layer, and the roller adds new, fresh powder on top of it, thereby gluing it to the binding of the previous layer. The previous steps are then repeated layer by layer until the desired model is complete. The part is then removed from the printer and placed in the post processing chamber, where a high-powered jet of air is used to blow away any excess powder. This powder is then recycled and automatically used in the next build. Finally, a part can be coated in wax, strengthening the part (Ben Utela, 2008) (Kathy Lu, 2008).

One of the biggest advantages of this machine is that it can be printed as much of a variety of colours as the customer pleases. This process can be done in a variety of polymers. The main disadvantage is that the delivered products are mostly weaker than other methods (Cooper, 2001) (J. W. Halloran, 2011).

Figure 15 shows a schematic build of a 3DP machine. The same as the SLS machine but with an adhesive instead of a laser. Everything moves in the directions of the red arrows.

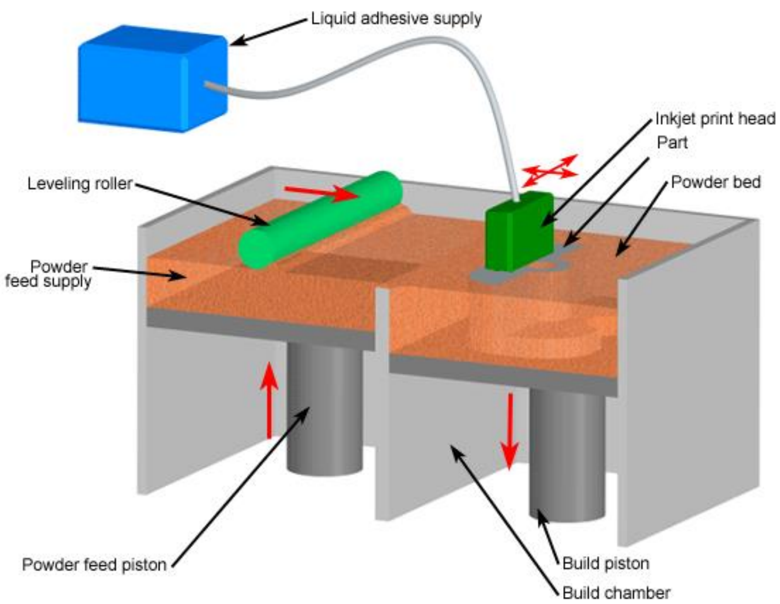


FIGURE 15. Schematic build of a 3DP machine (Net, 2008)

2.6.9 Prometal

This is a process mainly used for building dies and injection tools.

Before building a print, the build plate and feed plate are filled with powder. The level roller then moves across the powder to smooth it out. Once a smooth layer of powder has been created, a new part can be loaded into the program using a STL file as in the other methods. This method is a layer by layer process that alternates each layer with powder and binders (Beer, 2006).

This part requires a lot of post-processing. So, when the part is finished, it may be removed from the printer and placed in the curing oven. This curing process takes approximately 2 hours.
The part is now in its very fragile green state, only held together by binder. The surrounding powder can then be removed from the object using a paintbrush and air duster.
The part is then prepared for the sintering alloy. Where a layer of aluminium oxide is added to a ceramic crucible. After that, one side of the crucible is filled with bronze powder and a sacrificial block is placed on top of the bronze. The part can then be placed on top of the aluminium oxide with the peg touching the sacrificial block. Powder is added to the sacrificial block, to guarantee connection between the block and the peg of the part. The part can now be moved into the sintering oven, where it will be infused with the bronze. Within 9 hours, the part can be removed (D. W. Lipke, 2010).
At this point, the part is ready to be finished. The peg is then removed from the part and the part is ready to be polished to its final state (Cooper, 2001) (Kruth, 1991).

The most common used material for this method is stainless steel powder although the same process can be done with different sintering temperatures and times. For example, for rocket nozzles, they use tungsten carbide powder sintered with a zirconium copper alloy. The properties of these products are better than the ones from CNC (J. P. Kruth, 2005).

2.7 Comparison of Additive Manufacturing Methods

There is a dramatic difference in both strength, corrosion, accuracy, … using different methods of additive manufacturing. “Both the method and material used have a considerable influence, but neither can u neglect the building direction of the printed part.” (G. D. Kim, 2008)

Although materials are also a considerable influence in this, figure 16 and 17 show the tensile strength of various additive manufacturing methods. As can be seen, Polyjet creates parts with high strength in both vertically and horizontal directions. Also, LENS creates one of the strongest products when comparing high end AM methods and materials.

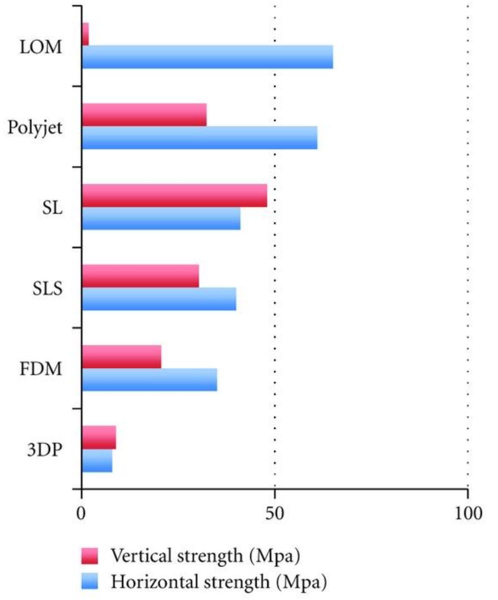


FIGURE 16. Tensile strength of various AM methods (G. D. Kim, 2008)

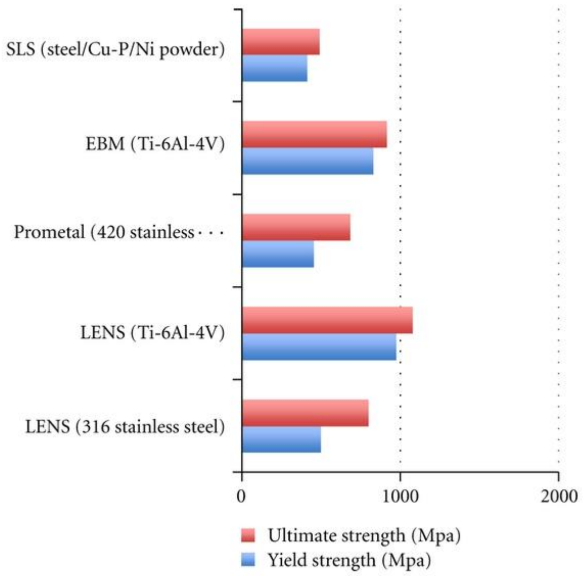


FIGURE 17. Tensile strength of various AM methods and materials (J. P. Kruth, 2005) (L. Facchini, 2009) (R. Shivpuri, 2005)

In the table below there are some of the attributes that are important to manufacturers and compared some of the different methods available (Dias, 2011).

TABLE 1. Comparison of AM methods

Attribute	SL	SLS	FDM	3DP	Polyjet	CNC
Quantity	-	-	-	-	-	0
Complexity	+	+	+	+	+	0
Surface Finish	0	0	-	-	0	+
Material Choice	0	-	-	-	-	0
Material Stability	-	0	+	-	-	+
Colour	-	-	0	+	-	-
Tolerance	-	-	-	-	-	+
Speed	+	+	+	+	+	+
Price - Low Volume	+	+	+	+	+	0
Price - High Volume	-	-	-	-	-	-

+ = good 0 = fair - = bad

2.8 Applications of Additive Manufacturing

Here this thesis will describe multiple applications of additive manufacturing. This shows that AM plays a significant role in all different kinds of industries.

According to Wohlers Report of 2014, this figure 18 shows us in which industries AM is being used and how big that industry plays a role in additive manufacturing methods.

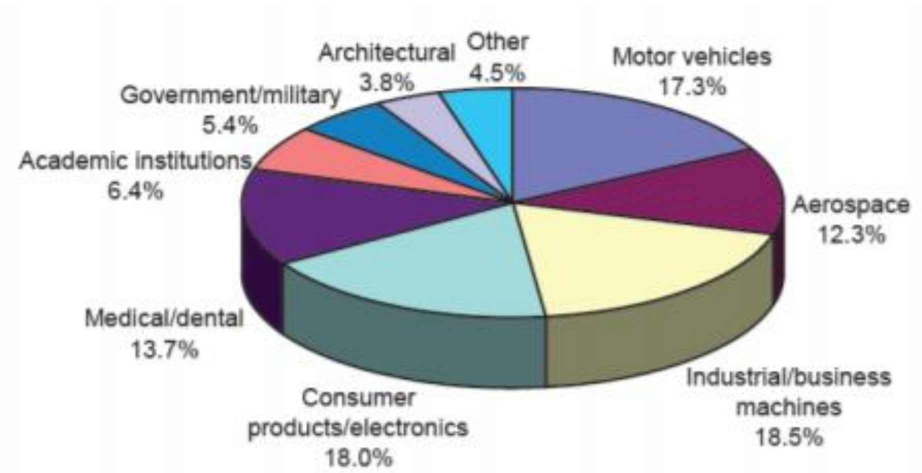


FIGURE 18. Applications based on industries (Wohler, 2014)

According to Wohlers Report of 2014, figure 19 shows what additive manufacturing is being used for. The percentage shows how much of the total revenue is being generated by that one particular field.

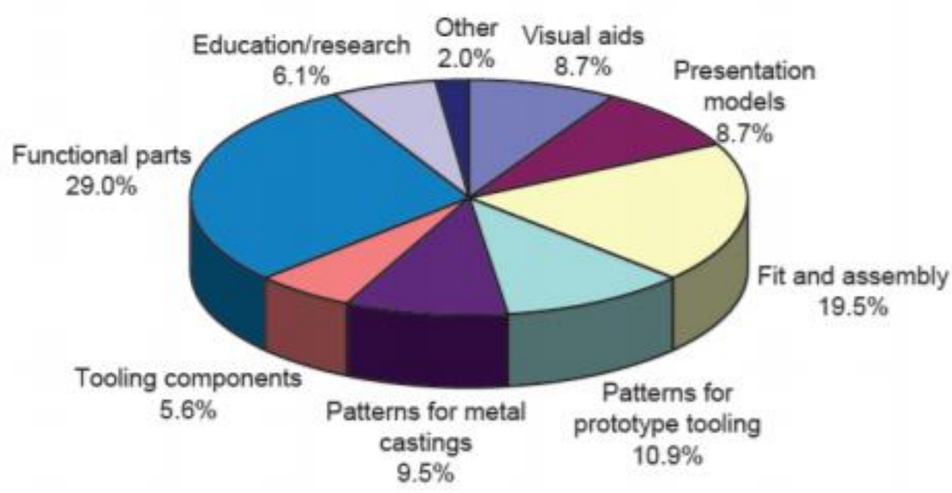
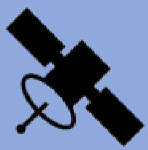
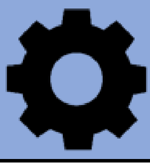


FIGURE 19. Applications based on end product (Wohler, 2014)

There are many more applications than shown on these figures, the possibilities are endless. In the next table, the industries which make the most use of additive manufacturing methods are shown as well as their most used purposes.

TABLE 2. Application of AM methods

Industry	Current applications	Potential future applications
	- Concept modeling and prototyping - Low-volume replacement parts - Structural and non-structural production parts	- Embedding additvely manufactured electronics direcly en parts - Complex engine parts - Aircraft wing components - Other structural aircraft components
	- Specialized parts for space exploration - Structures using light-weight, high-strength materials	- On-demand parts/spares in space - Large structures directly created in space, thus circumventing launch vehicle size limitations
	- Rapid prototyping and manufacturing end-use auto parts - Parts and assemblies for antique cars and racecars - Quick production of parts or entire	- Sophisticated auto components - Auto components designed through crowdsourcing
	- Protheses and implants - Medical instruments and models - Hearing aids and dental implants	- Developing organs for transplants - Large-scale pharmaceutical production - Developing human tissues for regenerative therapies
	- Rapid prototyping - Embedding electronic circuits into casings - Creating and testing design iterations - Customized jewelry and watches - Limited product customization	- Co-designing and creating with customers - Customized living spaces - Growing mass customization of consumer products
	- Specific parts replacement - Stronger and lighter parts	- Redesigning machines at the spot

In this table, most applications of additive manufacturing in the biggest industries are shown (logos, 2017) (2012).

3 PROJECT INTRODUCTION

3.1 Current state

The main, mechanical structure for this thesis is already constructed and available for our measurements and testing. This contains the very basic for this project. Meaning the frame, 2 of the prototype lockers, the big sprockets and chains (on which the lockers are placed).

Figure 20 shows what the project resembles before this thesis starts.

FIGURE 20. State of the project prior to this thesis

3.2 Available printers

For the purpose of this thesis, the parts will mainly be printed using the plastic 3D printer as this is a lot cheaper and faster to produce that parts that this thesis needs. Most parts that will be designed will have enough strength from the plastic. However, if it seems that after thorough testing, strength of some might not be sufficient, the same STL file can be uploaded into a metal printer for stronger and more durable parts. But since the metal 3D printer at our availability does not have the dimension required for this project, the prototypes will be printed in plastic. The printer at the availability for this thesis in TAMK university can be seen in figure 3 and 4, it represents a Prenta Duo XL and Ultimaker.

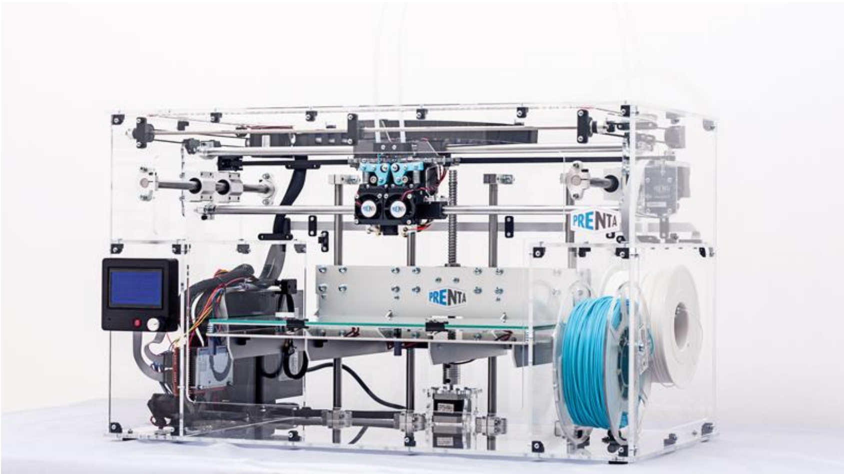


FIGURE 21. Prenta Duo XL (Prenta, 2017)

FIGURE 22. Ultimaker 2+ (Adafruit, 2017)

3.3 Dividing the project

3.3.1 Implementation

There will be three theses about this project. The implementation of this thesis will be discussed in the next paragraph. The implementation of the other theses will be about selecting the appropriate electrical motor and the automation of the i-Locker.

3.3.2 Implementation of this thesis

The aim of this thesis is to design prototypes using CAD software provided by TAMK. Prior to this thesis, nothing electrical was mounted, nor was there any sprocket attached for power delivery. This would be the implementation of this thesis.
Briefly said, this thesis will discuss the design of the brackets for the engine and PLC, sprocket for the main axle and individual locks (so the lockers don’t open when being moved). As a second topic, it will discuss the additive manufacturing method that is used and the progress in doing so. As last, this thesis will show the progress of fitting the prototype parts onto the project.

4 DESIGN

For the purpose of this project, SolidWorks 2016 was used. Available through TAMK and compatible with the available printers. As with all other CAD software, the first step to designing is getting to know the functions and capabilities of the program.

Through sketches a lot can be done. These sketches can be extruded into 3D objects and adjust them later with extra sketches, extrusions, fillets, etc. There are endless possibilities to create complex geometrics.

SolidWorks allows excessive testing of the product before it is produced. There is the possibility to test the product on strength, flexibility, airflow, sustainability, etc.
Choices can be made, for example what forces will be applied, where the fixtures are fixed, choose which material it is made off (from wood, to rubber, to metal), etc.

Figure 23 shows an example of the strength simulation on one of the brackets.

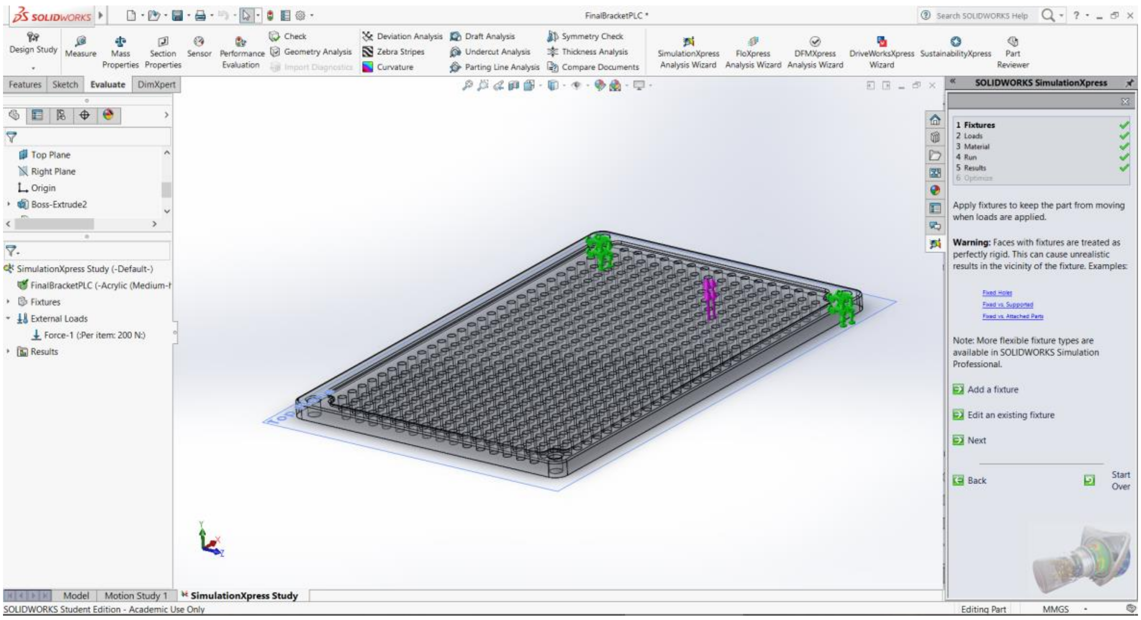


FIGURE 23. Simulation in SolidWorks

All upcoming figures under chapter 4 represent the CAD file of that part.

For the rotational forces applied in this project there is a maximum which will be used to calculate safeties and reliability. Twelve lockers will be mounted with an empty weight of 7 kg and a loaded weight of 20 kg each. If 6 are full on one side and 6 are empty on the other side. That means there is a weight of $20\ kg * 6\ lockers - 7\ kg * 6\ lockers = 78$ kg. This means with the earths gravitational force of 9.81 $\frac{N}{s^2}$, that there is a force of $78\ kg * 9.81 \frac{N}{s^2} = 765.18$ N applied in the worst case possible.

4.1 Main axle sprocket

Designing the main axle sprocket was done by sketching a circle and then applying a circular pattern with the dimensions so it can fit an ANSI 50 chain.
ANSI 50 stands for the dimensions of the chain. Including width and how big the gap is between 2 links. Since the lowest speed of the engine is 30 rotations per minute, so a ratio of 10/35 is needed (35 for the main sprocket and 10 for the engine sprocket) to make the lockers turn at the desired speed (Declercq, 2017).

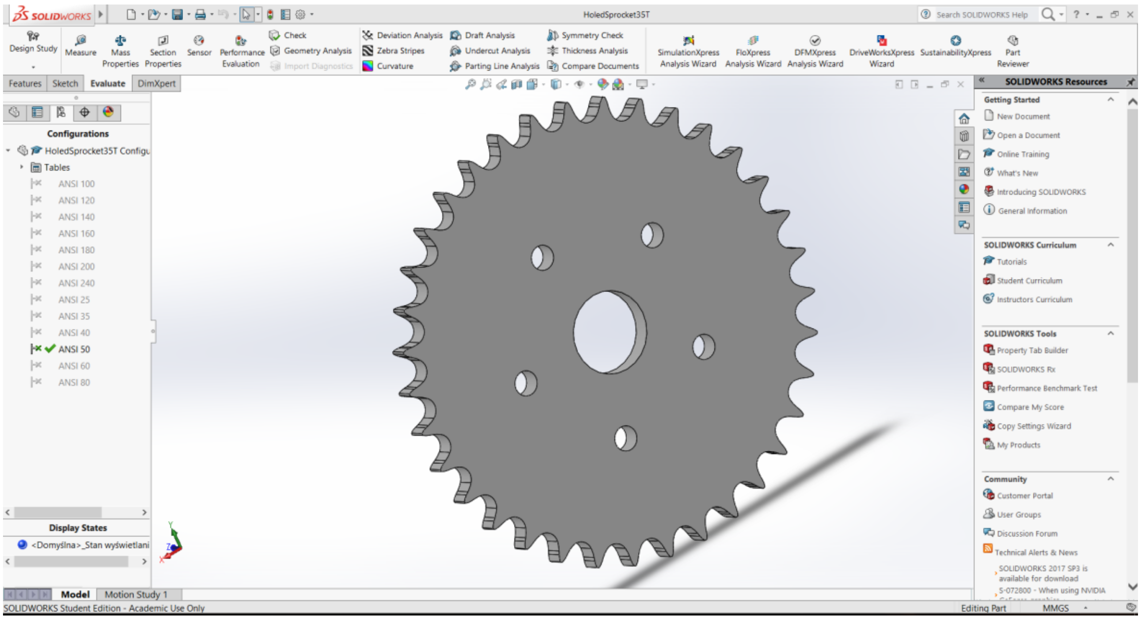


FIGURE 24. Main sprocket in SolidWorks

Through the use of a table, changing the number of teeth is just as simple as changing the number. But if this is changed, all the other dimensions will also be changed.

Finishing it off, the sprocket should mount over the main axle and thus an extruded cut was needed to make this possible. Extruded cuts were also needed to make sure 5 bolts could be used to attach the sprocket to the spacer.

Related strength calculations

In the next part, more details about the strength and calculated reliability can be seen. Using SolidWorks and strength calculations a guess can be made about the reliability of the created part.

Figure 25 shows the surface on which the chain will apply pressure.

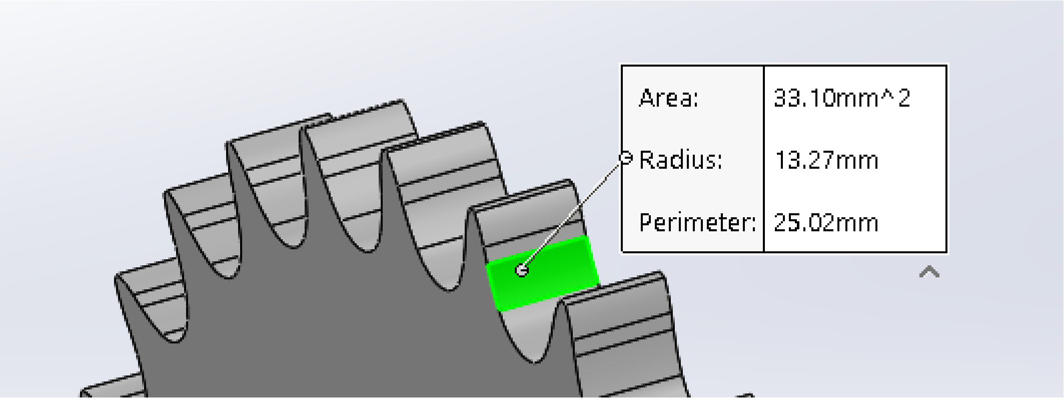


FIGURE 25. Contact area of the chain with the sprocket

Because all prints are made with the same material, PLA, one chart can show the strength of this material depending on the fill and resolution used.

TABLE 3. Strength of PLA depending on fill and resolution (3DMatter, 2015)

Strength [N/mm2]		Infill [%]						
		10	30	50	70	80	90	100
Resolution [mm]	0.1	8	12	17	25	29	33	39
	0.15	9	14	20	28	33	38	44
	0.2	10	15	21	30	35	40	46
	0.25	10	15	22	31	37	42	49
	0.3	10	15	22	31	36	42	48

As more than half of the sprocket will be in contact with the chain and the forces applied are pure rotational, at least half of the teeth will have contact.
This means the contact area can be multiplied with, calculating the number of teeth:

$$\frac{35}{2} = 17.5 \text{ teeth}$$

Rounding down for a safer evaluation and calculating the total contact area:

$$17\ teeth * 33.1\ mm^2 = 562.7\ \text{mm}^2$$

As seen in TABLE 3, the strength will be 15 $\frac{N}{mm^2}$, which makes the sprocket capable of handling:

$$562.7\ mm^2 * 15\ \frac{N}{mm^2} = 8440.5\ \text{N}$$

Giving it a margin of:

$$\frac{8840.5\ N}{765.2\ N} * 100[\%] = 1103\%$$

TABLE 4. Summary of the properties of the main axle sprocket (chain/teeth)

Part	Main axle sprocket (chain/teeth)
Printer	Prenta Duo XL
Resolution [mm]	0.2
Used material	PLA
Infill [%]	30
Strength of material [N/mm^2]	15
Contact area [mm^2]	562.7
Capability [N]	8440.5
Maximum applied load [N]	765
Pass or fail	Pass
Margin [%]	1103
Cycles	10^6

Calculations of the surface where the chain contacts the sprocket show that it is strong enough to handle applied forces. The sprocket has 5 holes where it is attached to the axle, these are the calculations for it.

Figure 26 shows the contact area of the bolts of the axle with the sprocket.

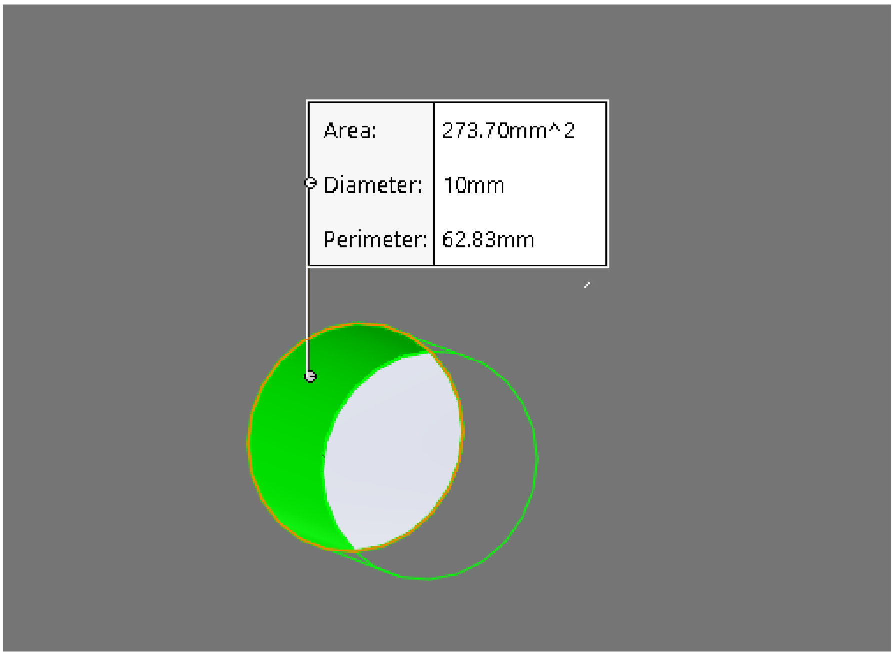


FIGURE 26. Contact area of the bolts with the sprocket

Only half of the area receives a force since there will always be only one direction in which the forces are applied. Thus creating 5 times the half of the area of the shown area. Calculating the total contact area:

$$136.85\ mm^2 * 5 = 684.25\ mm^2$$

Other calculations can be concluded from the previous ones and the results are shown in TABLE 5.

TABLE 5. Properties of the main axle sprocket (bolts)

Part	Main axle sprocket (bolts)
Printer	Prenta Duo XL
Resolution [mm]	0.2
Used material	PLA
Infill [%]	30
Strength of material [N/mm^2]	15
Contact area [mm^2]	684.25
Capability [N]	10263.75
Maximum applied load [N]	765
Pass or fail	Pass
Margin [%]	1342
Cycles	10^6

4.2 Spacer

Because the main sprocket can’t be attached directly to the main axle due to chains running against each other, a spacer would have to be placed in between them.

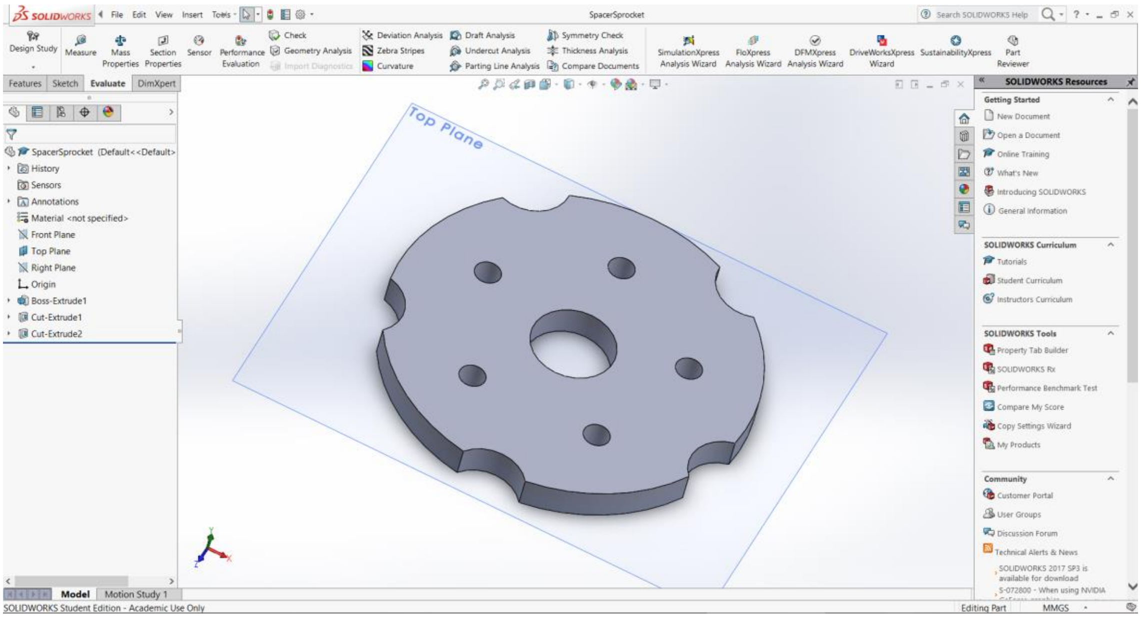


FIGURE 27. Spacer in SolidWorks

The same procedure was done with the spacer as with the main sprocket.

Since there are less forces applied on this part compared to the main sprocket, while it is also thicker and thus having more contact area, no calculations are necessary.

4.3 Engine sprocket

The design of this sprocket is done in the same way the design of the sprocket around the main axle but with some small adjustments. The main adjustment is of course the number of teeth and the recess that is needed to mount it to the engine instead of the bolts.

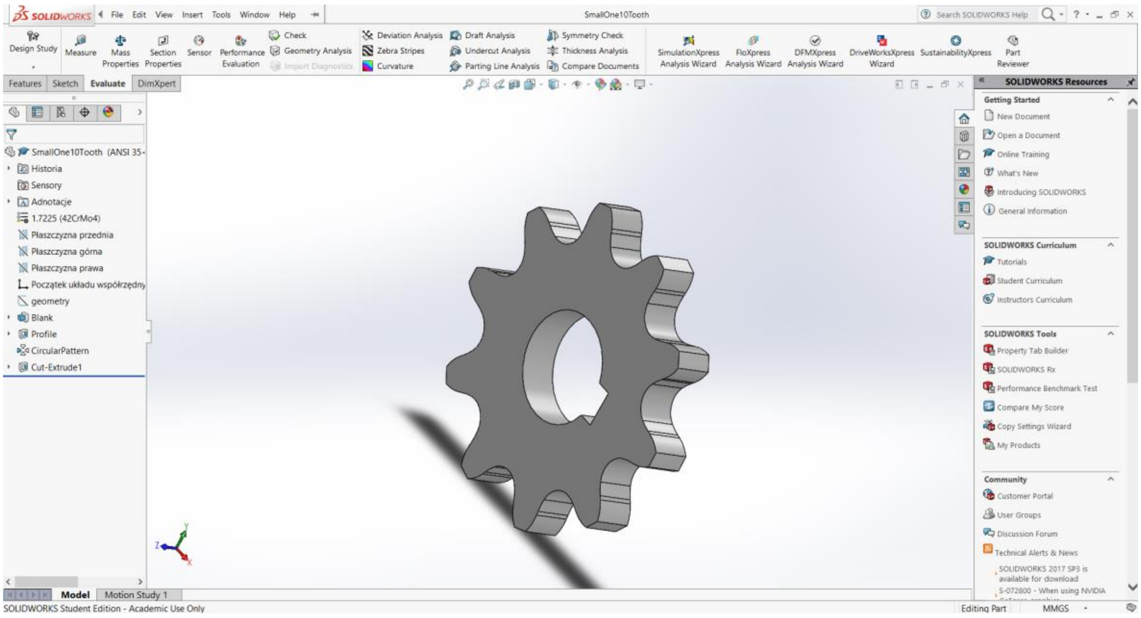


FIGURE 28. Sprocket of the engine in SolidWorks

As this is linked to the main sprocket, the same requirements are needed to fit an ANSI 50 chain on the engine sprocket.

Related strength calculations

In the next part, more details about the strength and calculated reliability can be seen. Using SolidWorks and strength calculations a guess can be made about the reliability of the created part.

Figure 29 shows the surface the chain will apply pressure.

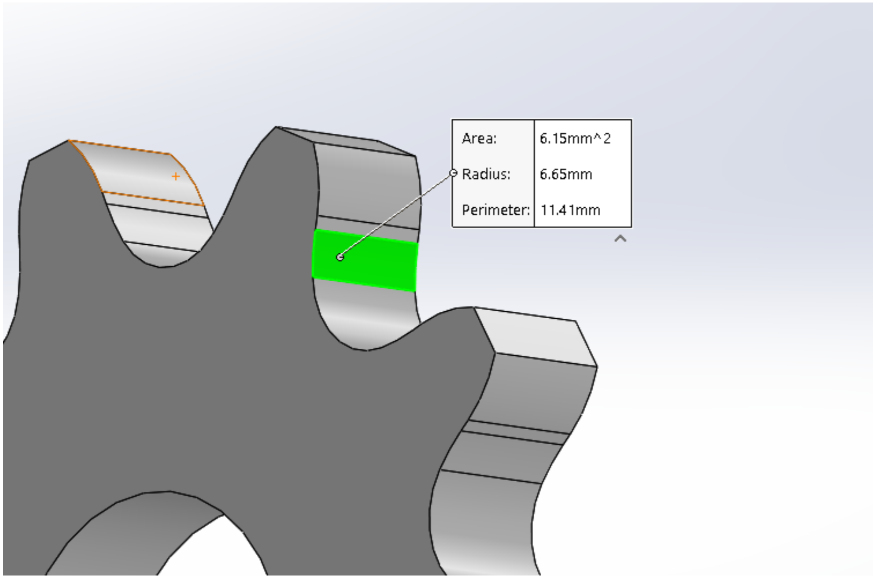


FIGURE 29. Contact area of the chain with the sprocket of the engine

According the calculations of the main sprocket, with adjusted characteristics, these are the calculated properties. With a contact area consisting of 4 teeth

$$6.15\ mm^2 * 4 = 24.6\ mm^2$$

Figure 30 shows the contact area of the engine axle with the recess in the sprocket, this is where the forces will be applied.

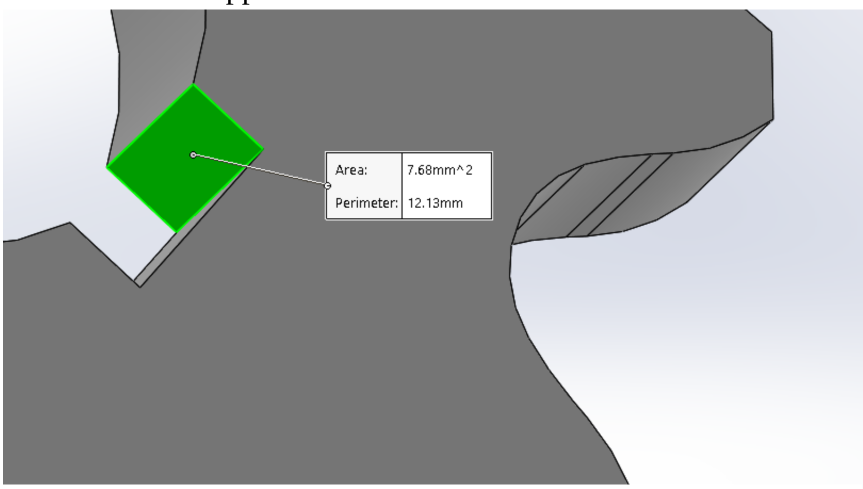


FIGURE 30. Contact area of the recess with the engine

TABLE 6. Properties of the engine sprocket (chain/teeth)

Part	Engine sprocket (chain/teeth)
Printer	Ultimaker 2 extended+
Resolution [mm]	0.25
Used material	PLA
Infill [%]	100
Strength of material [N/mm^2]	49
Contact area [mm^2]	24.6
Capability [N]	1205.4
Maximum applied load [N]	765
Pass or fail	Pass
Margin [%]	158
Cycles	10^{6}

The margin is much smaller on this sprocket since the contact area is a lot smaller than with the main axle sprocket. Even when using the best setting to create the best composition of the available material.

TABLE 7. Properties of the engine sprocket (recess)

Part	Engine sprocket (recess)
Printer	Ultimaker 2 extended+
Resolution [mm]	0.25
Used material	PLA
Infill [%]	100
Strength of material [N/mm^2]	49
Contact area [mm^2]	7.68
Capability [N]	376.32
Maximum applied load [N]	765
Pass or fail	Fail
Margin [%]	49
Cycles	10^{6}

If this product would be used in PLA, it will fail at the recess and break. When recalculating with new materials, shows a minimum tensile strength of 100 N/mm^2 is required for the sprocket to be durable enough. Any metal except aluminium would suffice.

4.4 PLC bracket

This bracket will support the PLC, power supply unit and some connectors. We always tried to smooth the edges so there is less risk for the maintenance crew to hurt themselves. We opted for this kind of design because we wanted it to be easy to add or remove parts to this bracket.

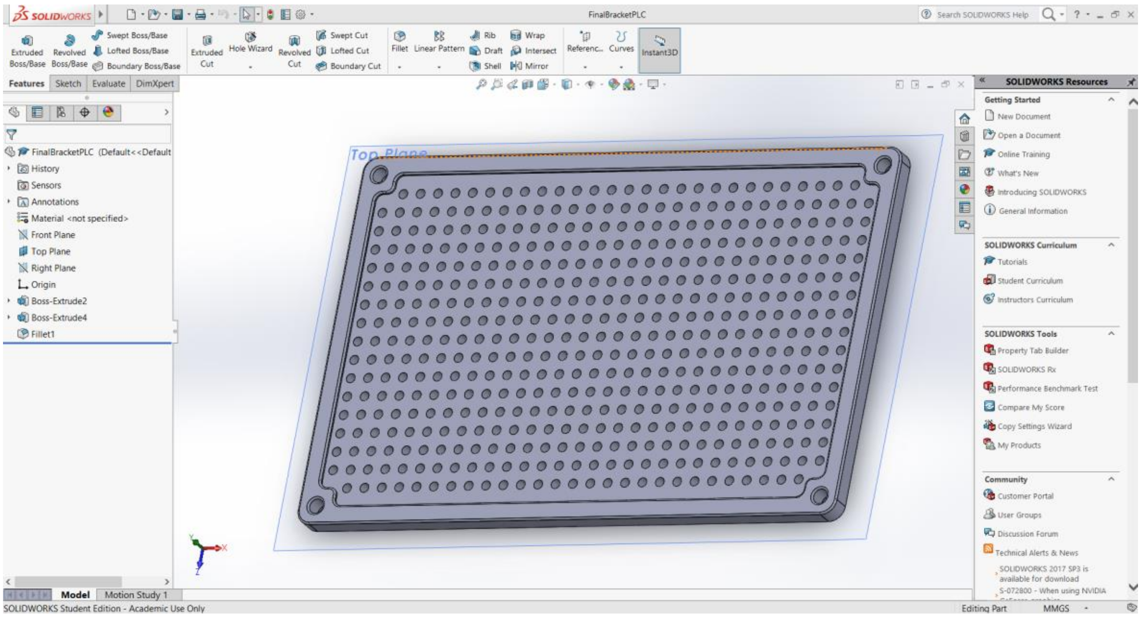


FIGURE 31. PLC bracket in SolidWorks

The PLC bracket does not apply any significant force and does not weigh a lot so there is no need for calculating as it can be said that this product will be strong enough.

4.5 Engine brackets

There are four 3D printed brackets for the engine because we want to enclose the engine and reduce the strain on each of these parts. It consists of the main bracket where the engine is being supported, two side connectors and one connector for the top.

4.5.1 Main bracket

This part supports the engine weight and allows the connector to be mounted on the electric engine.

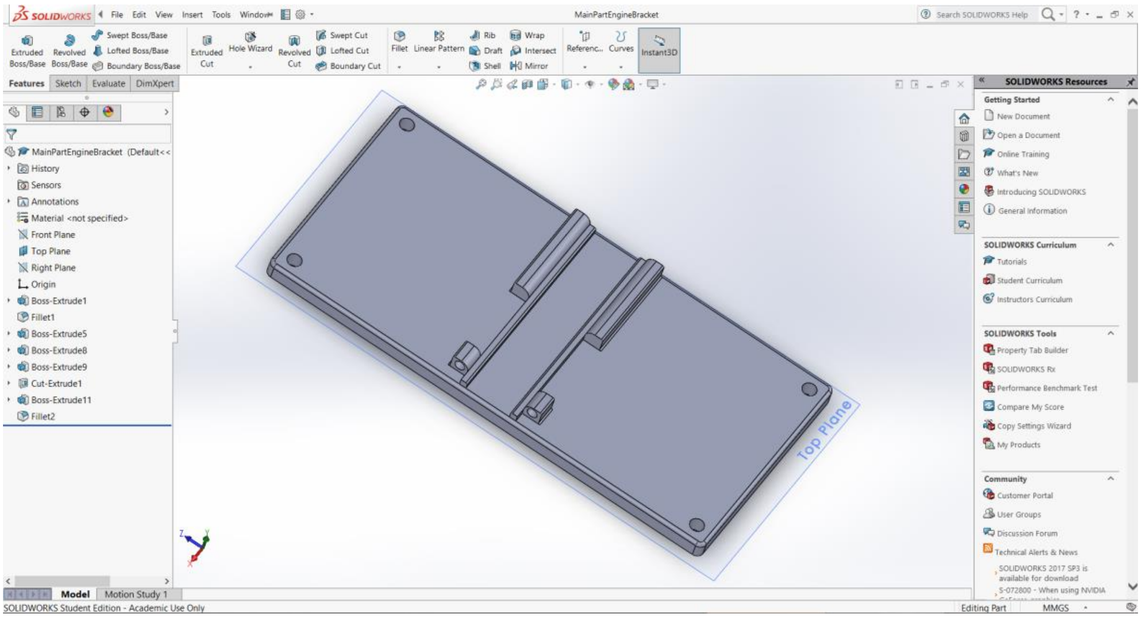


FIGURE 32. Main bracket for the electric engine in SolidWorks

4.5.2 Side connectors

This part connects the bottom bracket to the upper connector and is mounted on both sides of the electric engine.

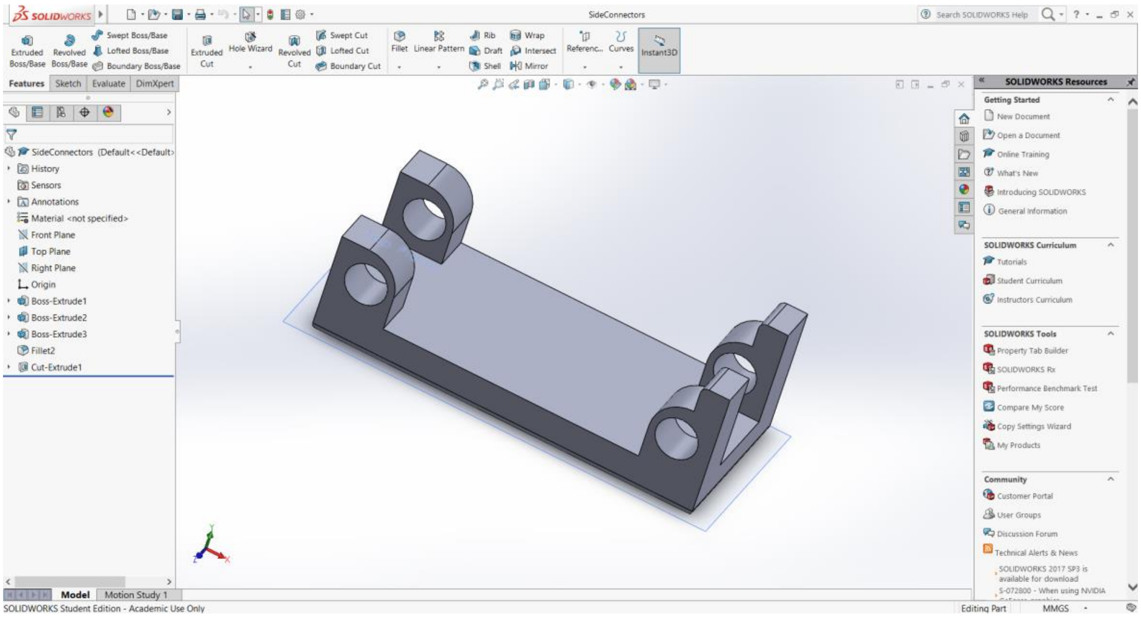


FIGURE 33. Side connectors for the electric engine in SolidWorks

4.5.3 Top connector

This part connects both side connectors and is the final part to the assembly of the brackets for the electric engine. It therefore encloses the engine.

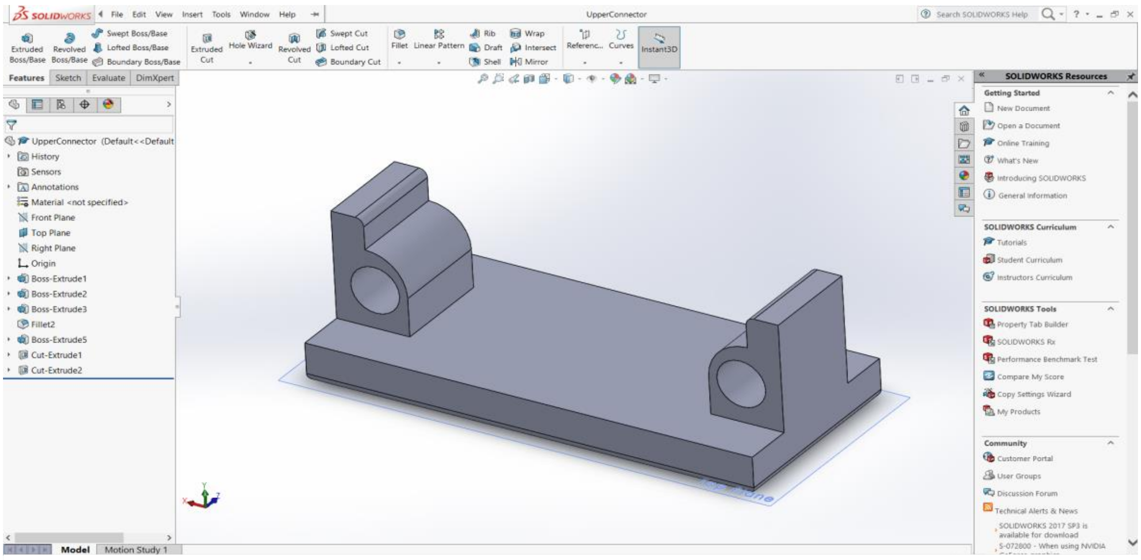


FIGURE 34. Top connector for the electric engine in SolidWorks

Related strength calculations

The contact area on this part is very big and has many different contact points so for the purpose of these calculations, the biggest contact area will be shown and used. The main part is made to catch the biggest forces and the side and upper connecters are there to make sure the engine can't move a lot.

Figure 35 shows the contact area of the engine with the main bracket.

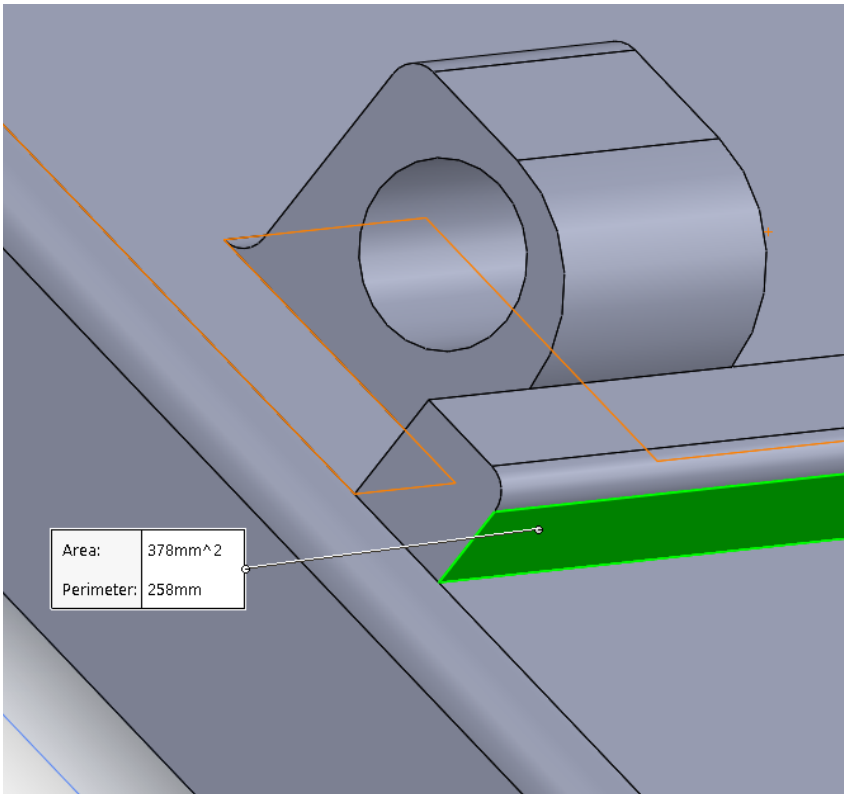


FIGURE 35. Contact area of the engine with the main bracket

TABLE 8: Properties of the main engine bracket

Part	Engine main bracket
Printer	Prenta Duo XL
Resolution [mm]	0.2
Used material	PLA
Infill [%]	30
Strength of material [N/mm^2]	15
Contact area [mm^2]	378
Capability [N]	5670
Maximum applied load [N]	765
Pass or fail	Pass
Margin [%]	741
Cycles	10^6

4.6 Lock

This part is to keep the lockers closed while they are not being used. It consists of four parts which will be mounted on each locker individually.

4.6.1 Main part

This is the part that keeps the slider in place.

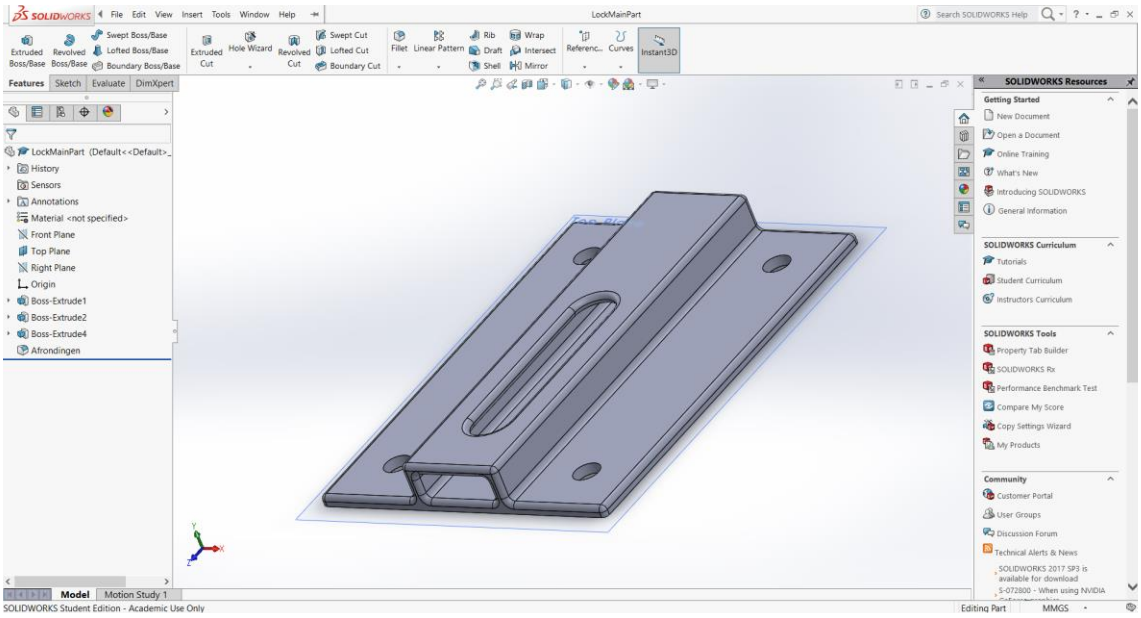


FIGURE 36. Main part of the lock in SolidWorks

This part is designed that on each side of the slider, there is a tolerance of 0.5mm. Allowing the slider to slide fluently between both brackets.

4.6.2 Opposite part

This is the part where the slider will be pushed in and actually keeps the locker closed.

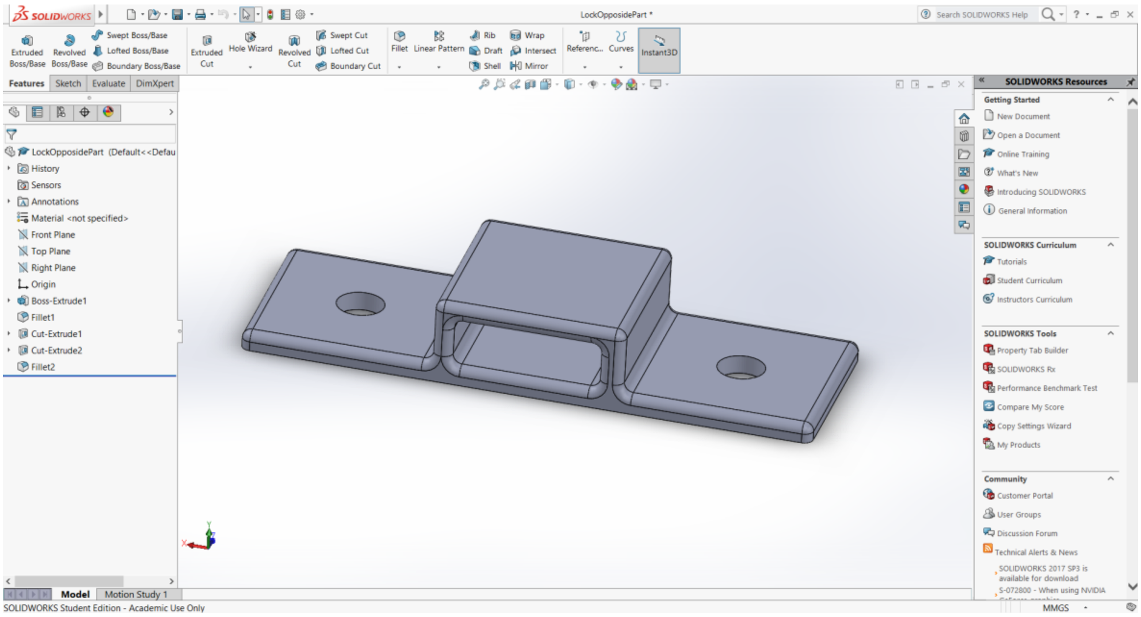


FIGURE 37. Opposide part of the lock in SolidWorks

4.6.3 Slider

This slider will be mounted into the main part of the lock and is used to span across the two surfaces to close the locker.

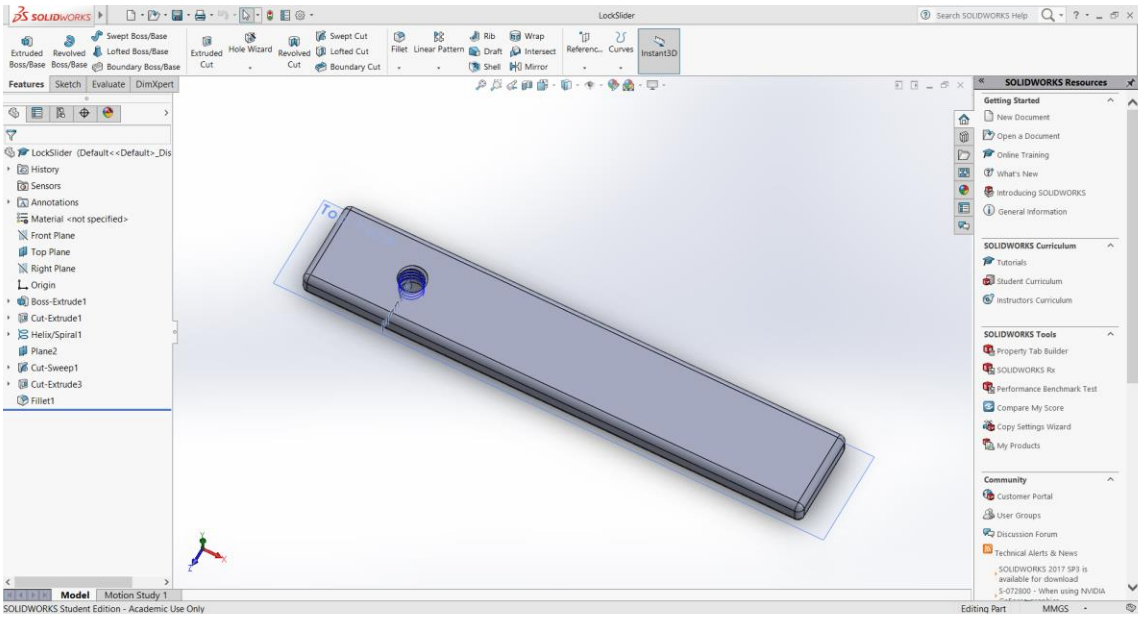


FIGURE 38. Slider of the lock in SolidWorks

4.6.4 Ball

This part will be attached to slider and keep it in place. It is screwed into the slider and makes sure it doesn’t leave the main part of the lock. It is also the place where the slider can be held and moved.

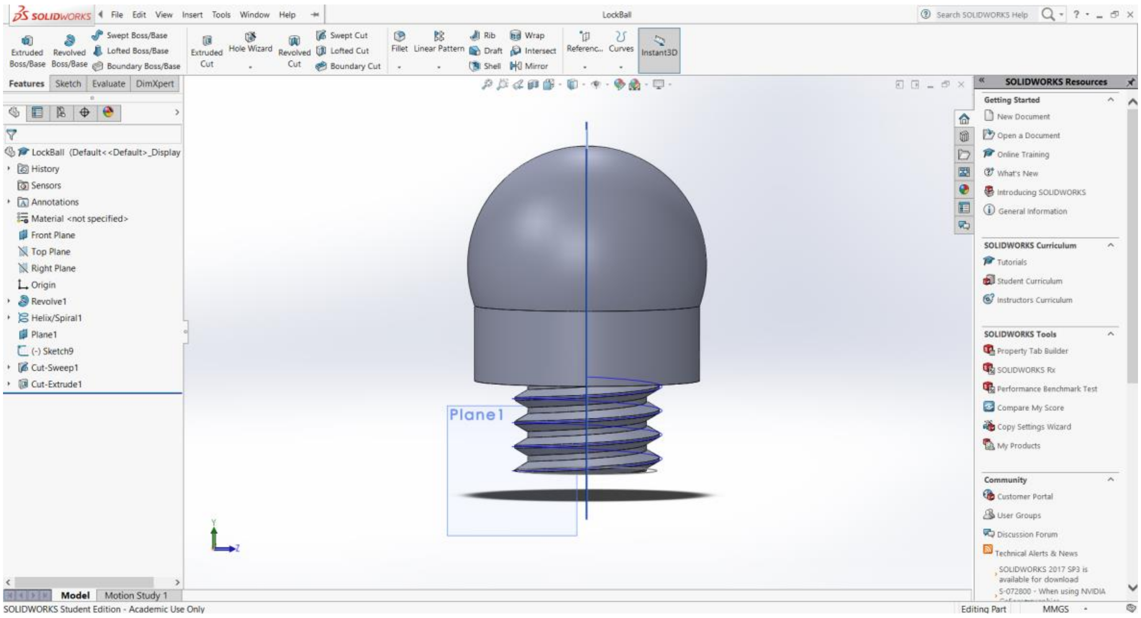


FIGURE 39. Ball of the lock in SolidWorks

3D designing thread is really difficult since the thread requires the use of a lot of functions. First a circle is sketched in the desired plane, converting it into a contoured helix across the plane/cilinder where the thread will be located. Here specifications can be done, including how many rotations the thread has to make and the distance between 360 degrees. To create thread, a triangle in the specific size of the desired thread is drawn so that it will fit the inner thread of the part where it will be assembled, here, the locker. This traingle should then be used to make a revolved cut around the contours of the helix previously created. Designing the thread on the locker was also difficult, the same steps had to be done.

After printing, conclusions were made that M5 thread is too small to print and that either bigger thread should be used or none at all. Another option is to glue parts together.

Forces applied to the lock are very small, maximum load of the locker is 13 kg, pushing towards the bottom of the locker, while the lock is located at the top. Calculations are not required as this will definetly hold.

5 SIMULATED ASSEMBLY

As last tests, some of the parts that required assembly, were virtually assembled to see if they would fit together. This is done in SolidWorks and gives a good visualisation of how the parts will fit.

5.1 Main axle sprocket and spacer

The spacer and main axle sprocket would be fitted together. Through SolidWorks, an assembly can be made to be sure the parts would line up perfectly. This is done through uploading both parts into an assembly file format in SolidWorks and mating them as desired.

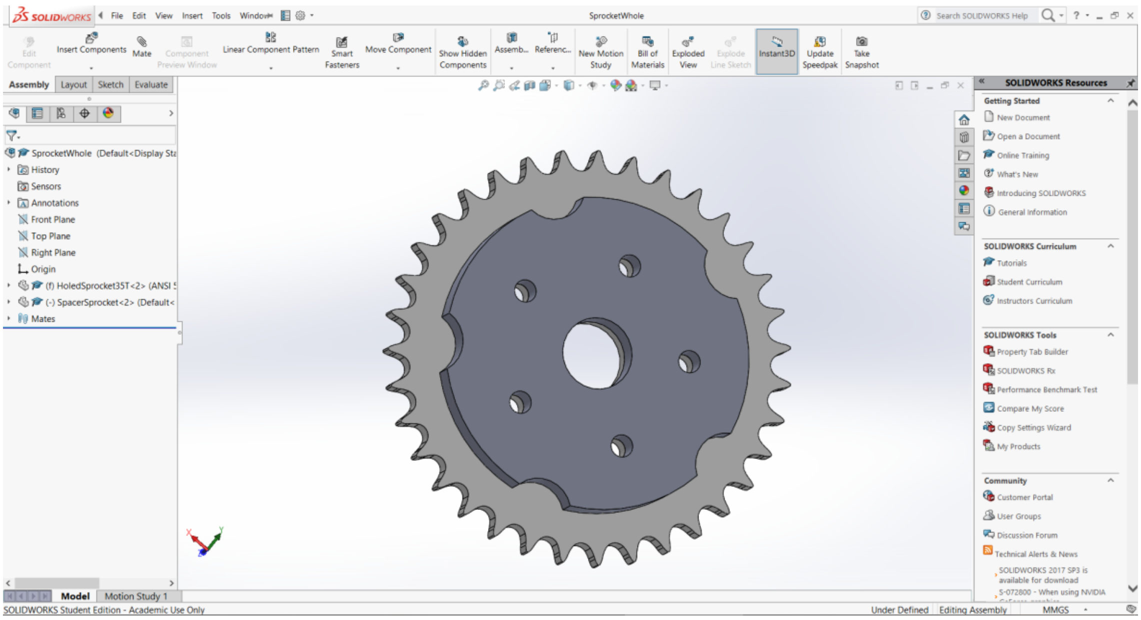


FIGURE 40. Assembly of the main sprocket and spacer in SolidWorks

5.2 Engine bracket

This is the part that needs the most assembly, as can be seen in the next figure, everything should fit and line up. Because of this assembly, mistakes were found in the first design. Concluding that an assembly can be very useful for troubleshooting and adjusting the parts when mistakes are found. More specifically, the side connectors were designed with too much support so it would overlap with the main bracket.

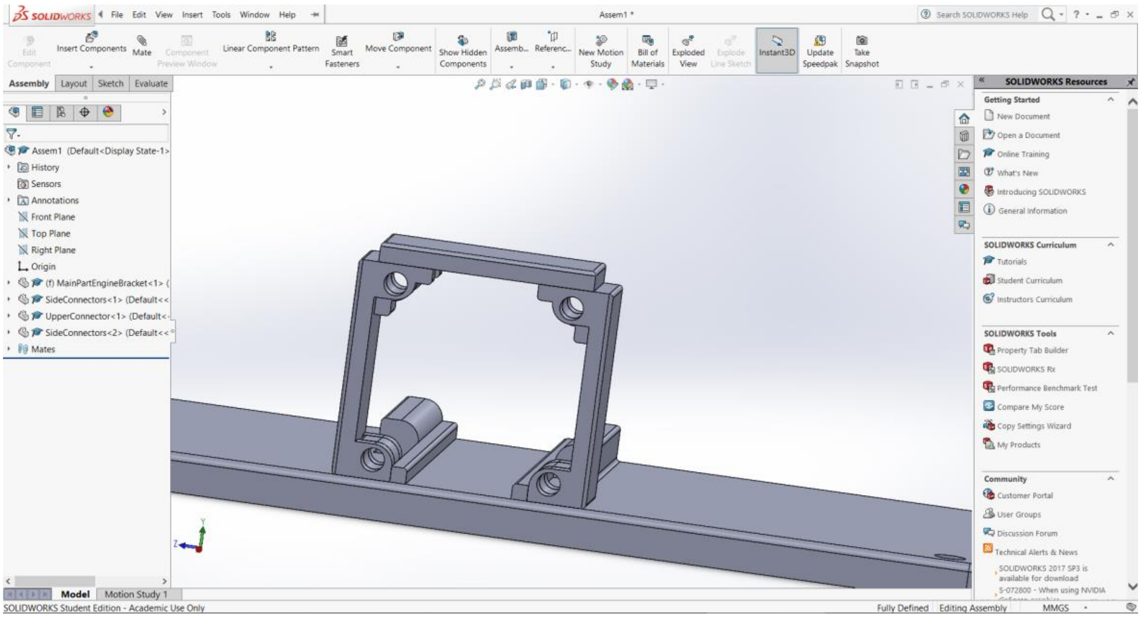


FIGURE 41. Assembly of the engine bracket in SolidWorks

5.3 Lock

The lock was designed part by part and made an assembly to check if the slider fits in both brackets. Mating the desired parts and making limits to the travel distance of the slider so it would not exit on either side.

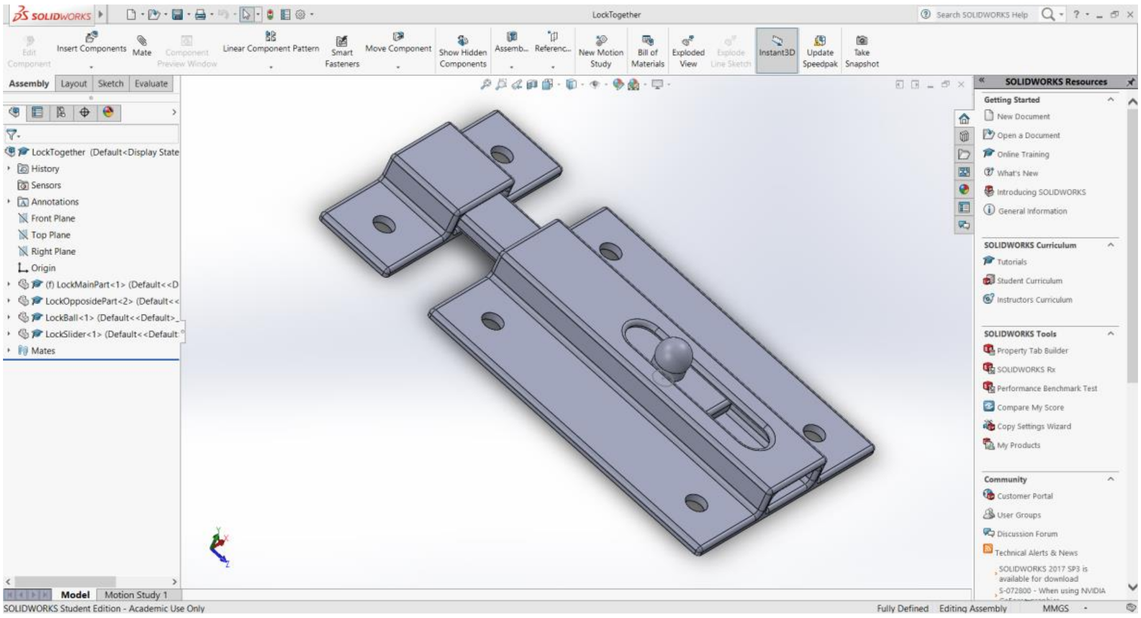


FIGURE 42. Assembly of the lock in SolidWorks

6 PRINTING

For printing the parts, the material PLA (polylactic acid) was used, which is the most common material used in consumer based printers. This is good because PLA is biodegradable. Pure PLA is not strong mechanically, therefore, they add additives to it to get better properties.

The used printer is a Prenta Duo XL, since this printer has decent dimensions (40x20x20cm), we were able to construct all my parts using it. This printer has dual nozzles so you can add another material, either for colour or the making of support structures. It also has a heated bed, which helps the printer to keep the part warm as it is being produced. Thus, it prevents warping. Warping is the uneven cooling down of the plastic, the sides cool down faster and could therefore deform. Conclusion, a heated bed drastically increases the quality of the print.

Figure 43 shows a picture of the printer (Prenta Duo XL) in action, more in particular, the printing the bracket for the PLC.

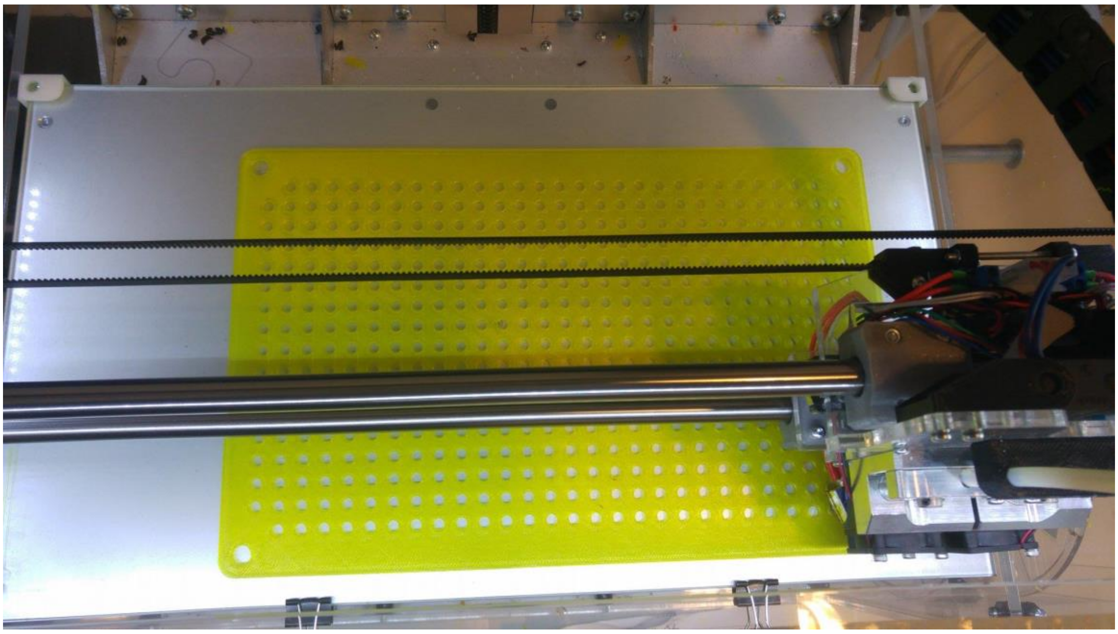


FIGURE 43. Prenta Duo XL in action

7 FITTING

In this chapter, the fitted parts and what their purpose is, is discussed.

This spacer creates space between the big sprocket and the main axle sprocket. This is to avoid the interfering of the chains with each other. The sprocket, attached to the spacer and main axle, is used to transfer the power, through the use of a chain, from the electrical motor to the main axle on which the bigger sprocket and lockers are attached.

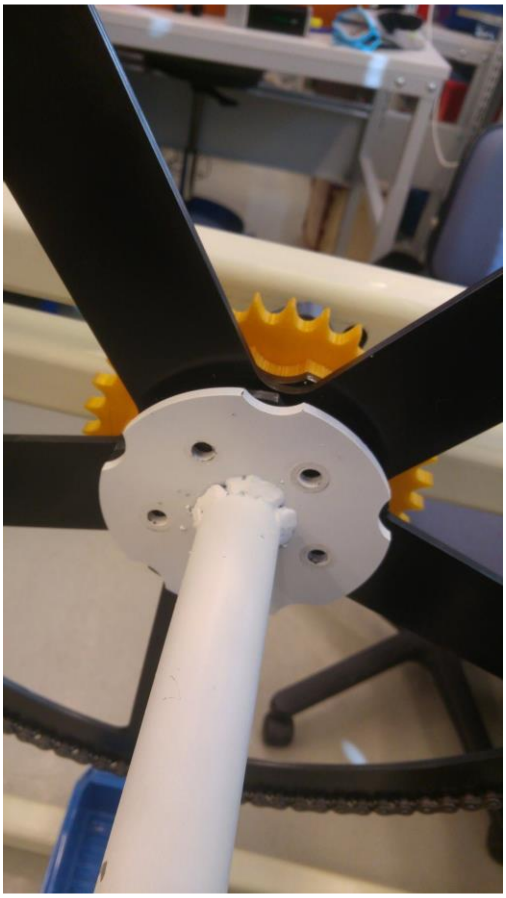


FIGURE 44. 3D printed spacer and sprocket attached to the main axle

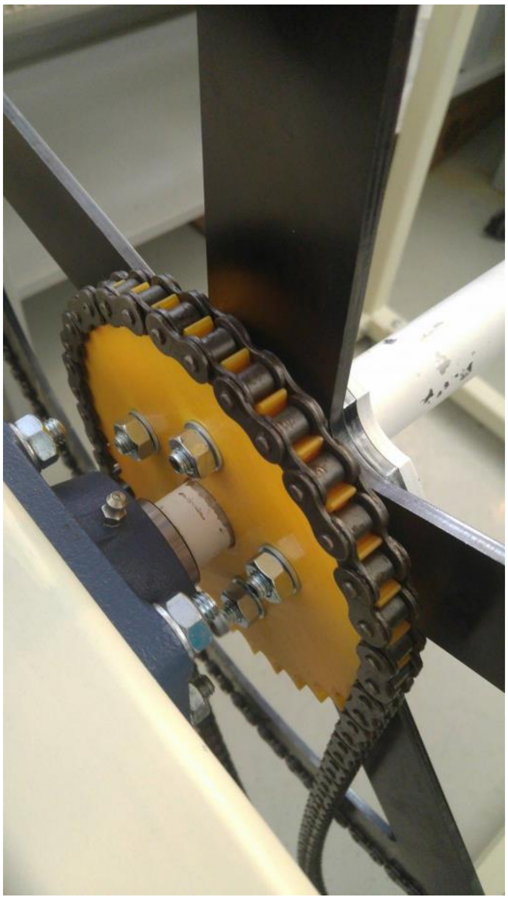


FIGURE 45. 3D printed sprocket linked through the use of a chain

This bracket is used to attached future electrical parts, including PLC, power supply and connectors. The holes are made for M5 bolts as these are the most common used for PLC rails.

FIGURE 46. Bracket for electrical parts

This is the lock mounted on individual lockers, it has no safety feature as that is done through sensors and PLC. The purpose is to keep the hatch closed when the locker is moving.

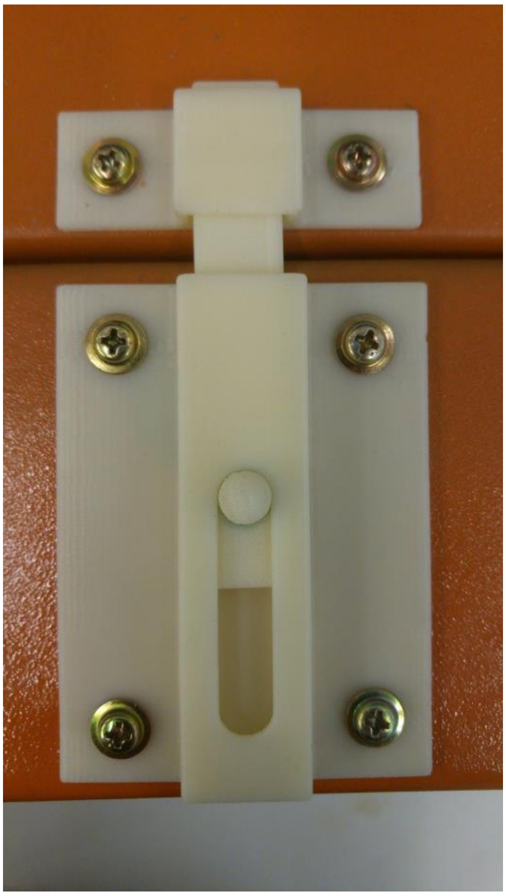


FIGURE 47. 3D printed lock attached

8 CONCLUSION

8.1 Summary

In the theoretical background, there is a lot of information about the software and files used additive manufacturing, the diversity of additive manufacturing methods and their advantages and disadvantages, the main benefits of these methods and where it is being used.

In the project introduction, the start of the project can be seen. Also, the implementation of this thesis and the goals are given here.

In the design chapter, difficulties of CAD designed are discussed and the possibilities of CAD software. Strength calculations are seen here and shows if a part will either pass or fail in the future. Designed parts are: individual locks (consisting of 4 parts: ball, main part, slider and opposite part), spacer and sprocket for the main axle, bracket for the electrical components, bracket for the electrical engine (consisting of 4 parts: main bracket, side connectors, upper connector) and the sprocket which is mounted on the electrical engine.

In the simulated assembly chapter, the parts are fitted together in a virtual simulation to make first observations and adjustments if necessary, before the actual manufacturing. This includes symmetry, accuracy (will it be mountable?) and fitting of the parts (will it slide into each other as required?). Assembled parts are: the individual locks (mated so that the slider can move into the desired position), the spacer and sprocket (mated so the holes line up) and the bracket for the electrical engine (mated so the holes line up and the engine is surrounded by connectors).

In the printing chapter, the used printer can be seen in action along with the progress of the part being printed, which material is being used and what advantages this printer has.

In the fitting chapter, the produced prototypes are shown, fitted onto the main frame of the project. This includes a finished lock, a spacer and multiple sprockets and brackets.

Suggestions for the improvement of the project are of course the mounting of the PLC and related electronics, so the programming can be done. Also, the engine sprocket can be improved. A straightforward way to solve this is by printing it in metal, which would create a more reliable product. More lockers should be made to complete the project and make it an actual product that can be used at public services. Also, the outside casing of the project should be finished so that it would prevent people from getting hurt or stealing material from the lockers.

8.2 Discussion

I, personally, am very happy with the results because I have done what was agreed and I am glad about what I have learned the last couple of months. I have never worked with SolidWorks before, I am now capable of making my own designs and complex geometrics through this program. I learned what it takes to convert a file, so it can be used with a printer.

I learned to work with Simplify3D and Cura to adjust, make support brackets and upload the STL files onto a readable SD card for the 3D printer. I also learned the basics of the available printers, this includes changing materials, the theory behind them, adjusting settings, their capabilities, etc.

I have fitted the parts discussed and it worked as a charm. The only part remaining to be done is the automation, which is going to be discussed in the thesis of Perttu Virkki.

Appendix 1 shows us how to use the basics of Simplify3D (does not include the scaling or offsetting of parts and making support structures).

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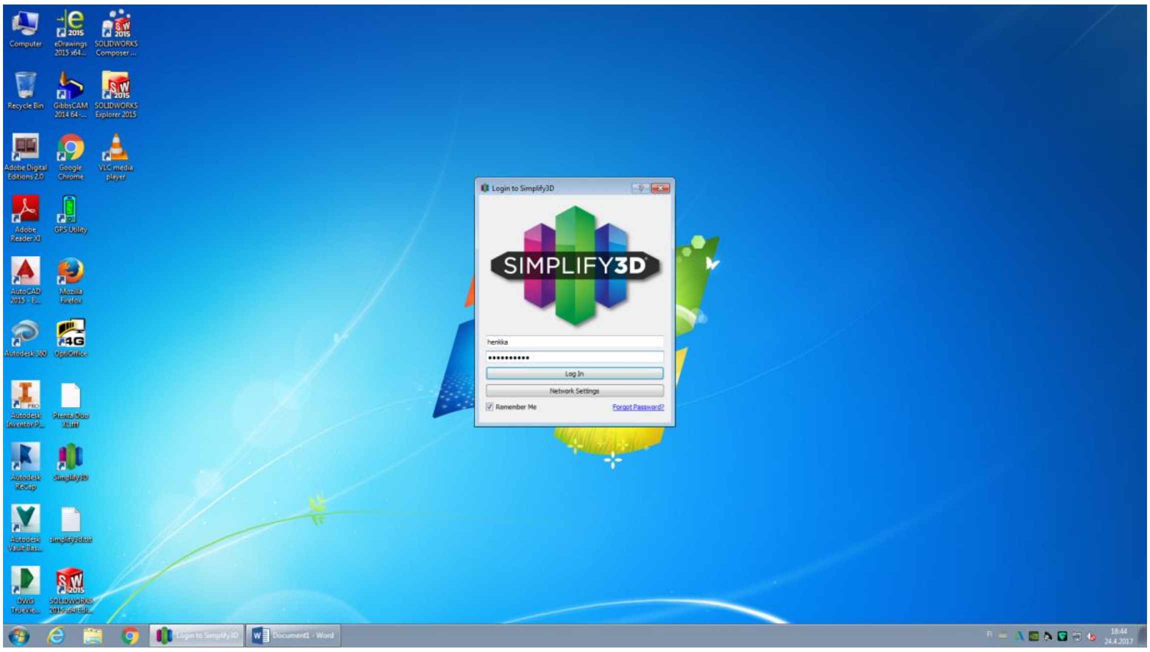
APPENDICES

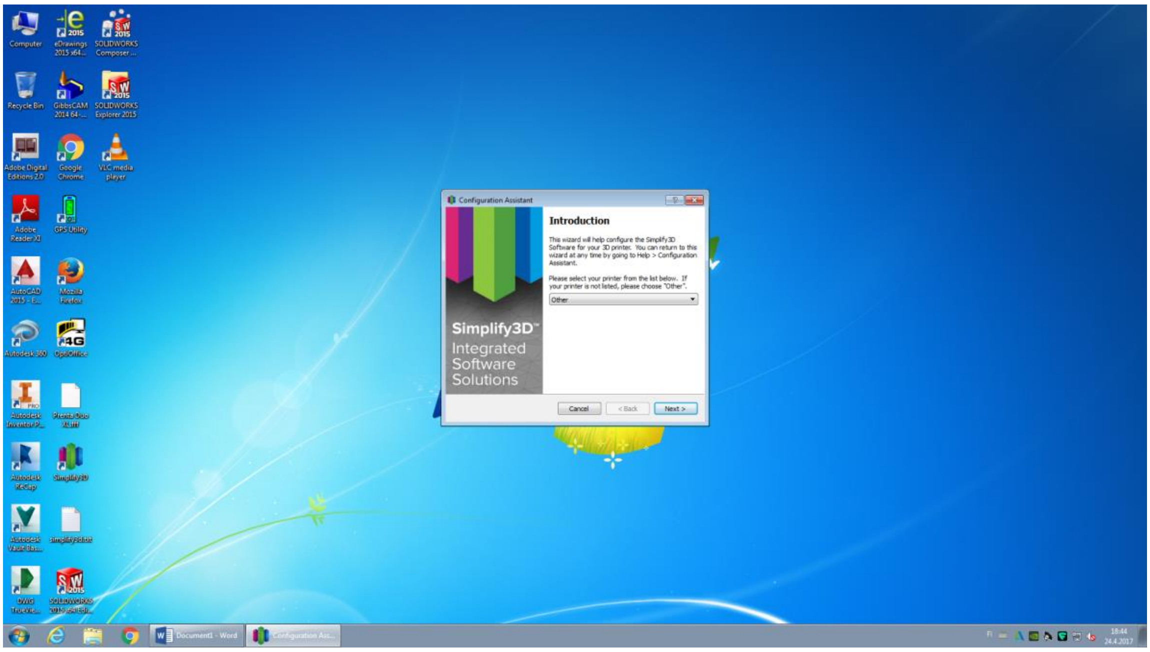
Appendix 1. How to 3D print through the use of Simplify3D

1 (1)

First, you open Simplify3D and type in your credentials, then press log in.

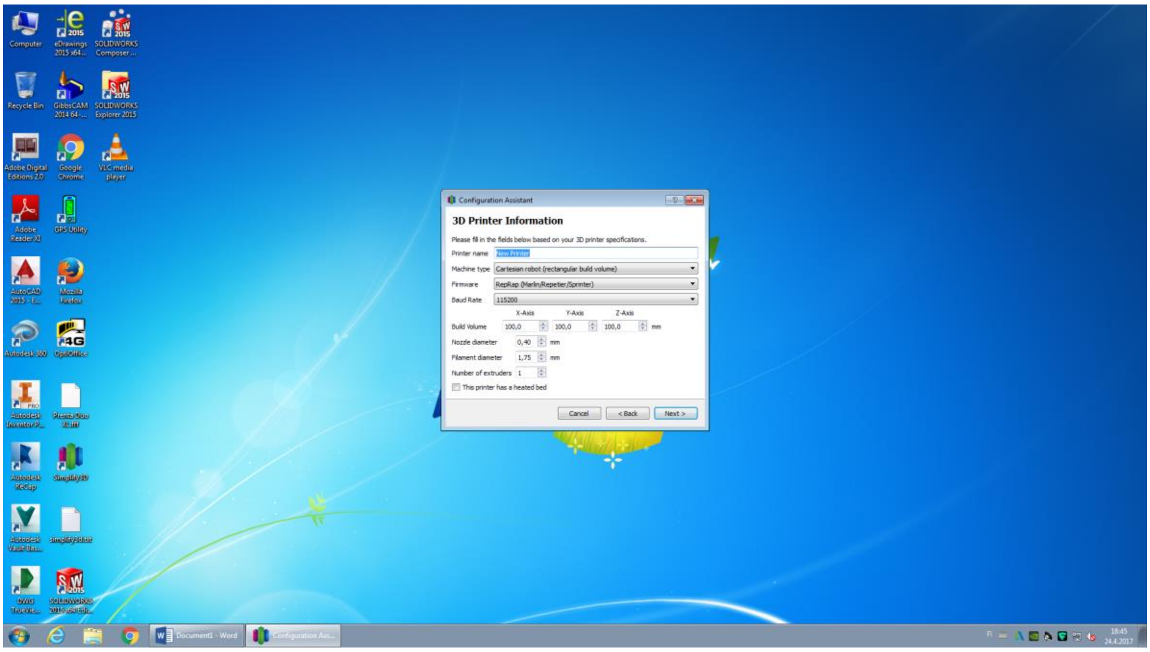


If the printer you are using, is not in the list that you will find in the introduction tab, you select others and then ”Next”.

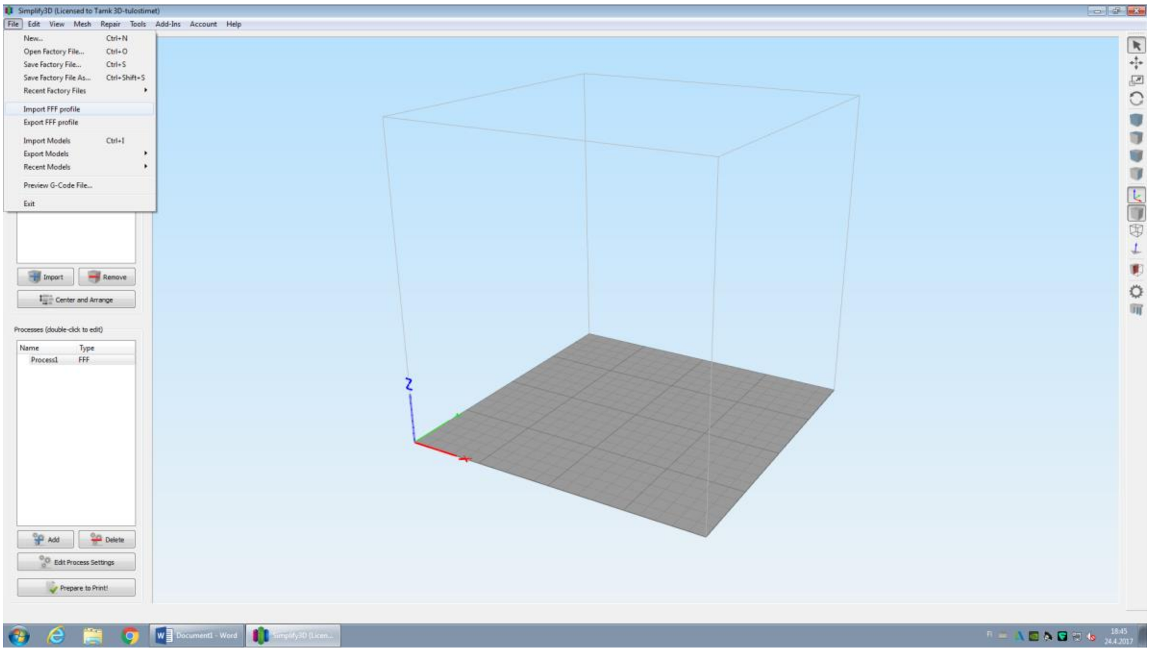


2 (1)

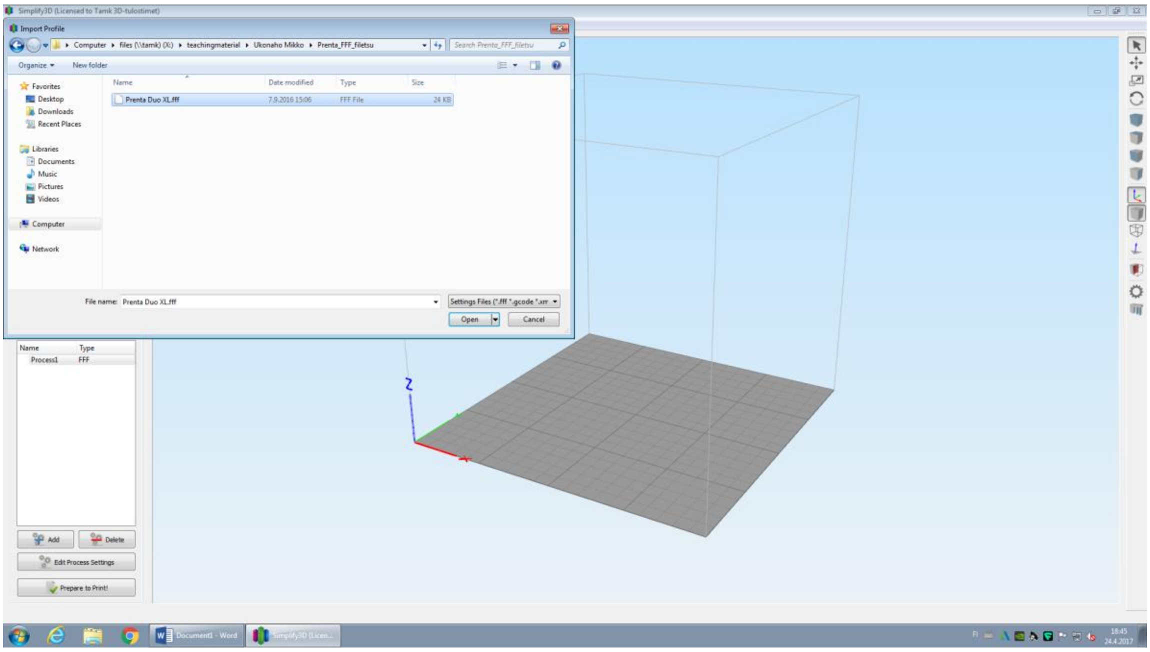
If you selected ”Other” as printer, you can give the specifications given by the manufacturer of your printer here and choose the fitting printer name. After you have completed this, press ”Next”.



If you have an FFF profile available, click on ”File”, then on ”Import FFF profile”. Go to the directory where you have downloaded or saved the FFF profile provided by your seller.

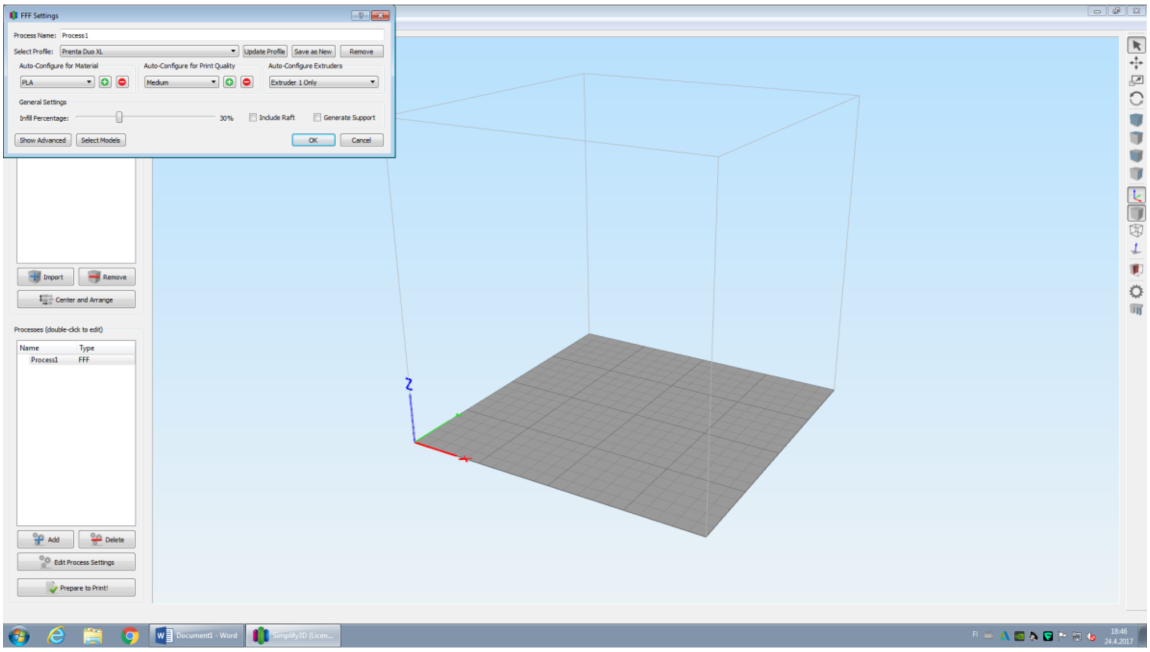


”Open” the FFF profile.



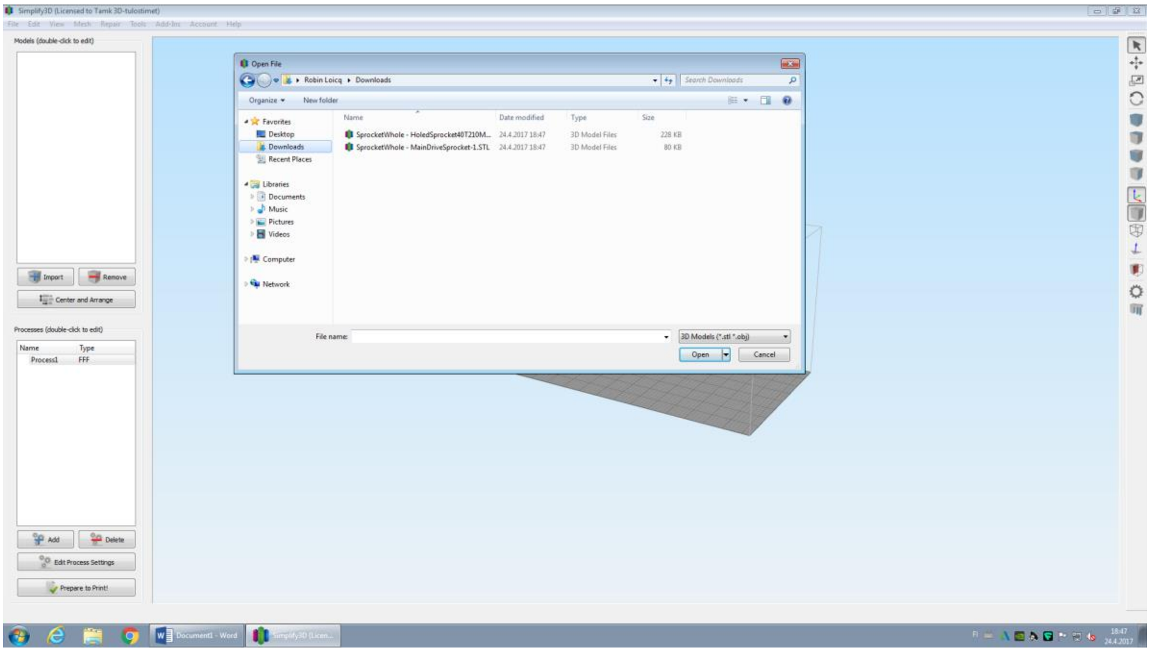
Here you can choose variable settings, like what material you use, how fine every layer should be, which extruder(s) to use, ...

If you have done this and are happy with the settings, press ”OK”.



When you have done all previous steps, you can now upload your own STL file.

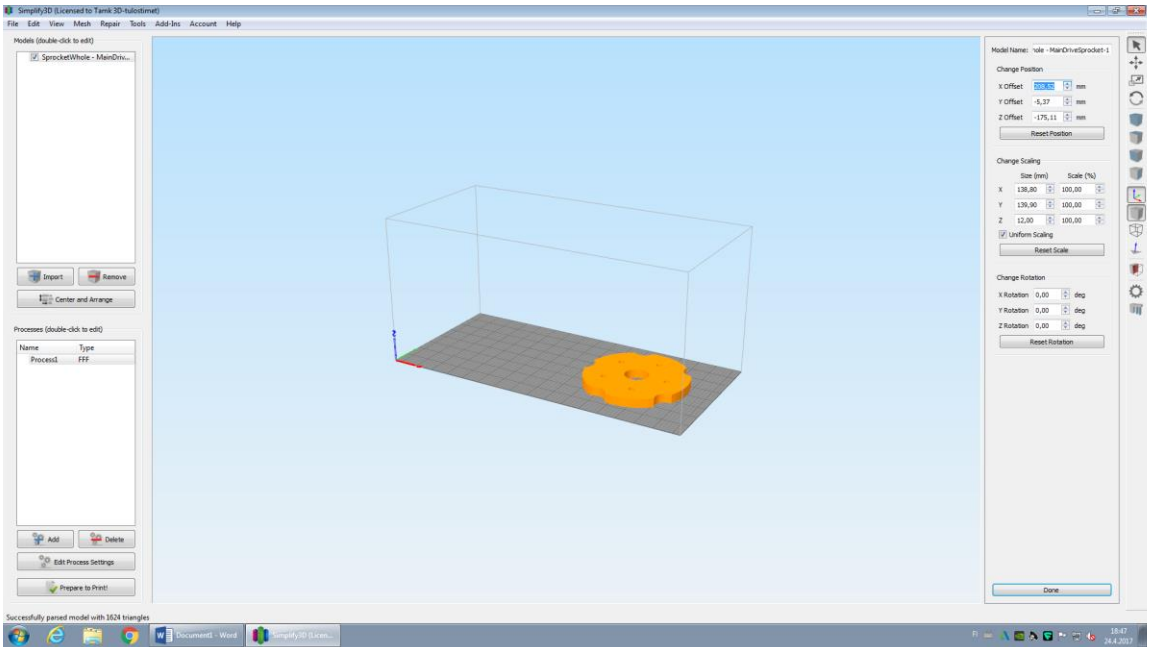
Press on ”Import” underneath the empty white box, go the directory where you have downloaded or saved the STL file and then ”Open” the desired file.



It should look like this.

When you double-click the part you want to adjust, you are able to scale, offset or rotate the part until the desired position is accomplished.

Then click ”Prepare to Print!” in the bottom left corner.



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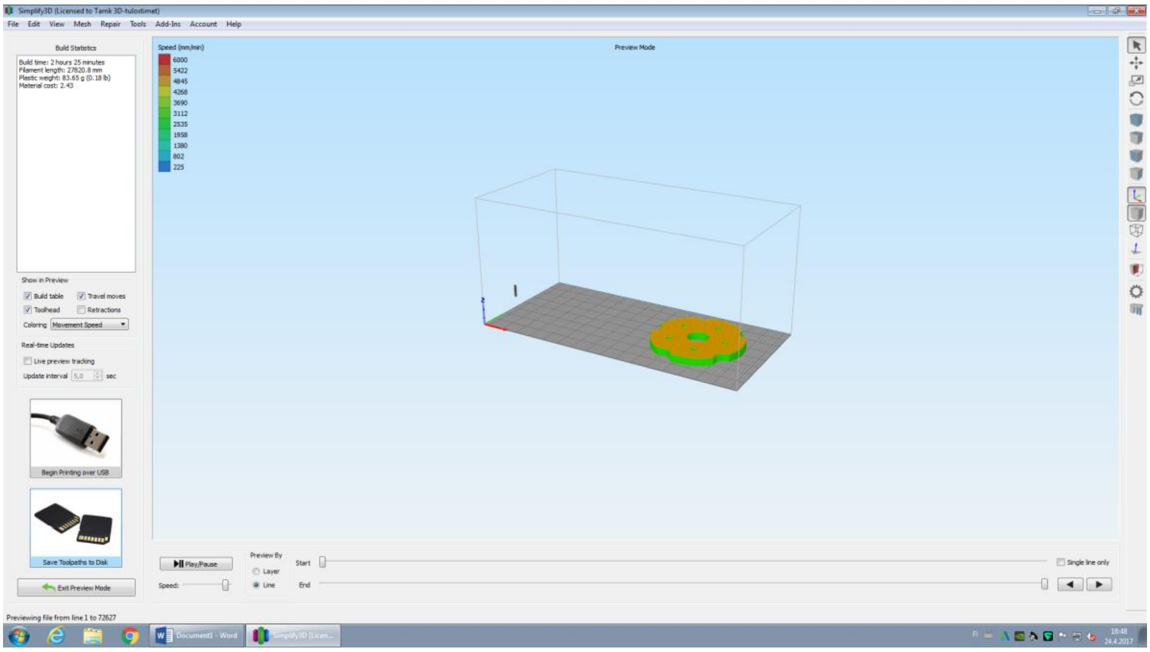
When you have the desired settings for your product, you can add your SD card to the computer and press ”Save Toolpaths to Disk”.



Once this steps have been done, you can insert the SD card into the printer, select the created .gcode file and start printing.