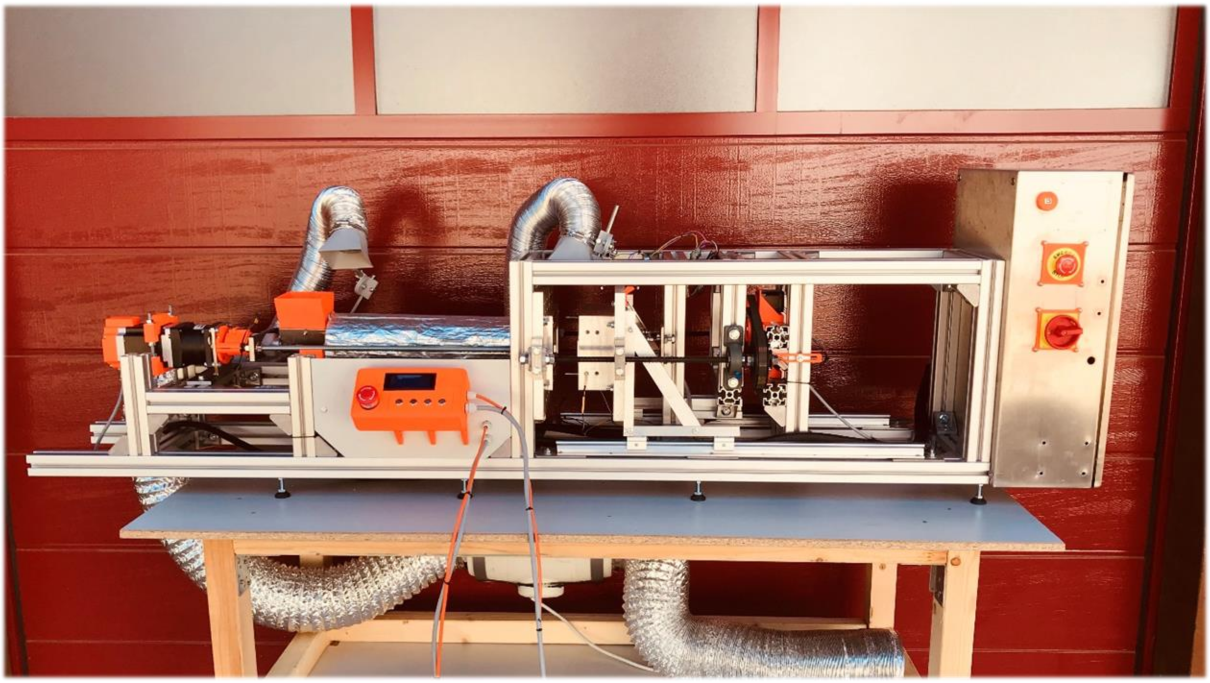
How-to build an automated injection molding machine, by SOTOP-Recycling



This machine was built by Manuel Maeder and Benjamin Krause between April 2019 and August 2020.

README

Hey there 😊 ,

cool that you downloaded this "how-to" package for our **Smart Injector**. This Folder should give you decent information on how we built our machine, how it functions, which parts we used and where we got them from.

We did not have the time and resources to make a detailed video or step-by-step description about the process of building it, but we hope this info in written form is still detailed enough for you. With this we want to help you to get started with an automated machine or help you upgrading your existing one. Or even just to inspire you to participate in projects that push plastic recycling😊.

Even better if you need to get a bit creative here and maybe discover some hacks and things, we did not take care of 😉.

DANGER, VERY IMPORTANT !!

If you have unsolvable questions about specific things in the mechanic or electronics, do not continue unless you know exactly what you are doing. Get help with the electronics/mechanics from someone professional. We want everyone to be safe and well off in the evening after a long working day 😊.

Before you consider building this machine:

The machine is not perfect yet. It works properly and injects phone covers properly, but for now it cannot be run completely without human interaction. There are still some small problems with clogging and clamping force. More on this in the **Troubleshooting** chapter.

Information on how the machine is built:

For a better understanding what we will be talking about in this document, check out all the pictures in the folder **Additional_pictures** and get a grip on the **CAD**. The cad is very essential to understand the machine. We did not add too many pictures in this document cause simply by looking at the CAD it is much easier to understand what the text is about. So parallel to reading about the components you should always check them in the CAD.

In the **BOM** is information about the components built into the machine. It is split into subgroups (frame, extruder, clamp mechanism, ...) to see easier where they are used. Not every single screw is listed in the BOM. It is just for having a compact reference of parts.

The **Blueprints** folder contains the latest versions of the components in the machine. Please consider that we are not professional designers and that mistakes can occur 😊.

Everything about the electronics is in the **Electronics** folder. Especially with electronics, do not do anything if you are not 100% sure of what you are doing. Let a professional person help you.

In the **Program** folder we added a program, that we used so far to run our machine. Since we are no programmers, it is certainly crappy and unreliable ^^. See it rather as a source of information and a backup but not as a full functioning program.

If you want to learn more about injection molding, before you start building a machine, we highly recommend reading the **Info_injection_molding** file from Arburg about injection molding (attached in this folder).

The machine has gone through several stages and is almost constantly upgraded. So please consider that not everything is perfectly synchronized. The pictures may not always display the current situation of the machine 😊

Specifications:

Maximum Torque extrusion screw	51 Nm
Motor Voltage	48 V
Input Voltage	230 V
Outer sizes	2000 mm x 300 mm x 500 mm (approx.)
Cycle time	4 minutes for an Iphone8 phone cover
Clamping force	9 kN
Daylight	180 mm
Shot size	25 g (works well, we did not test more yet)
Estimated cost	1000 Euros

01_frame:

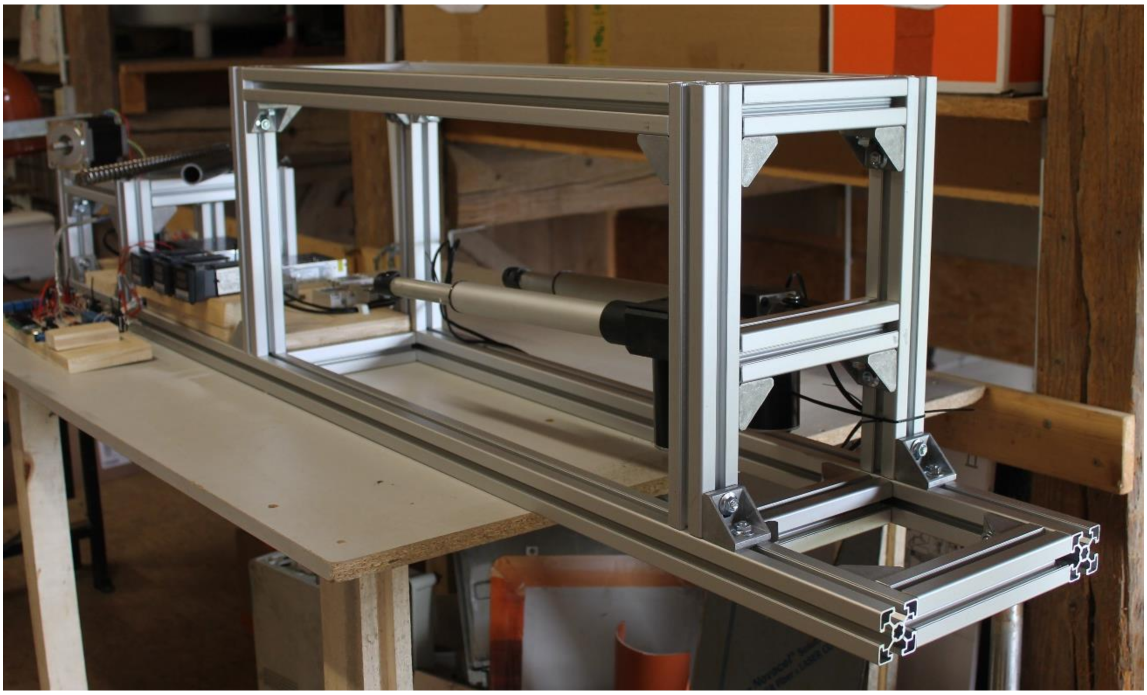


Figure 1 the frame at the very beginning

The structure, that keeps everything in place is an aluminum frame. It is simply Rexroth profiles 45 mm x 45 mm and with a T-slot for an easy mounting. To connect them there are mounting angles which you can easily screw and unscrew. In the machine there are approximately 50 of them.

The specific sizes of the frame are in the blueprint **01_*frame***. Note that the lengths of the profiles do not have to be as exact as specified in the blueprint. If in the range of +- 1 millimetre it is completely ok.

02_extruder

The extruder is driven by a NEMA34 stepper motor, connected to a planetary gearbox (6:1 ratio), connected to the extrusion screw. Specific info in the blueprint **02_*extruder***. The extrusion screw is from the precious plastic bazar, but unfortunately, we did not find the link anymore. It is a bit shorter in length than the screw from the extrusion pro machine.

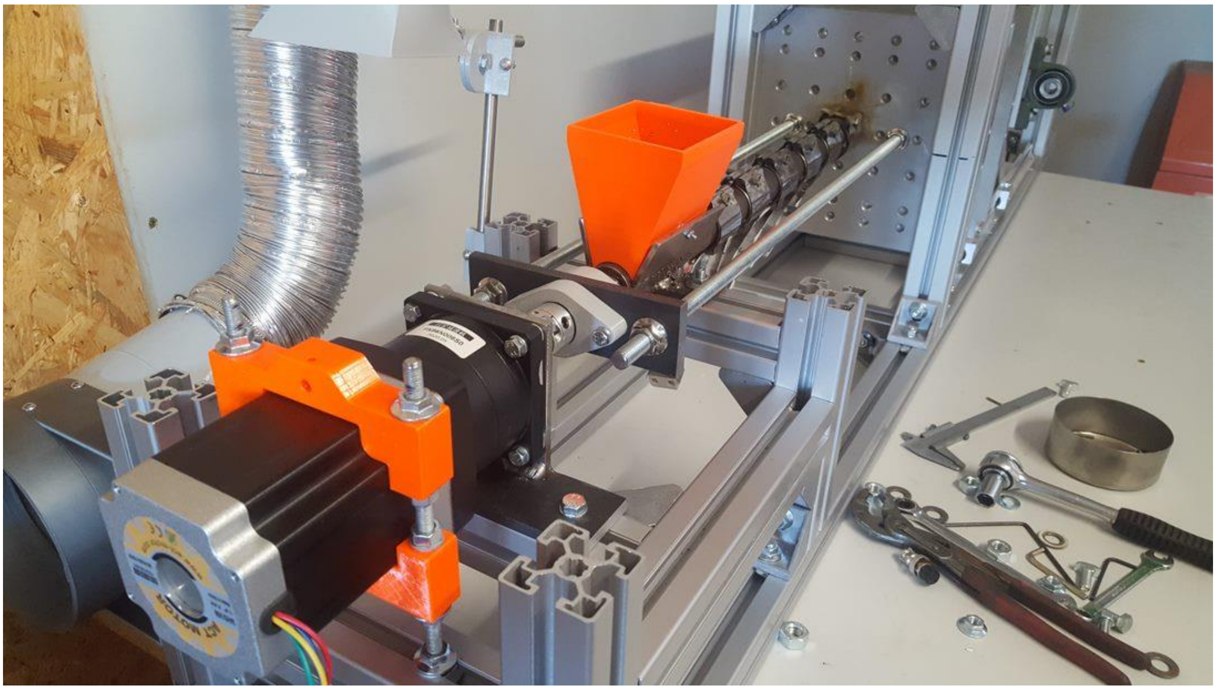


Figure 2 overview of the extruder without isolation

The extrusion screw transports the plastic flakes in the heating pipe (26 mm inner diameter). Around the heating pipe there are six heating sleeves installed. Each of them with 300 W of power consumption. They are controlled with three separate PID controllers, so it is possible to set three different temperatures along the pipe (We work with 240°C – 260°C – 280°C with 280°C being at the nozzle). The small nuts welded on the pipe fix the temperature sensors. Three of them are for the PID controllers and one from the Arduino.

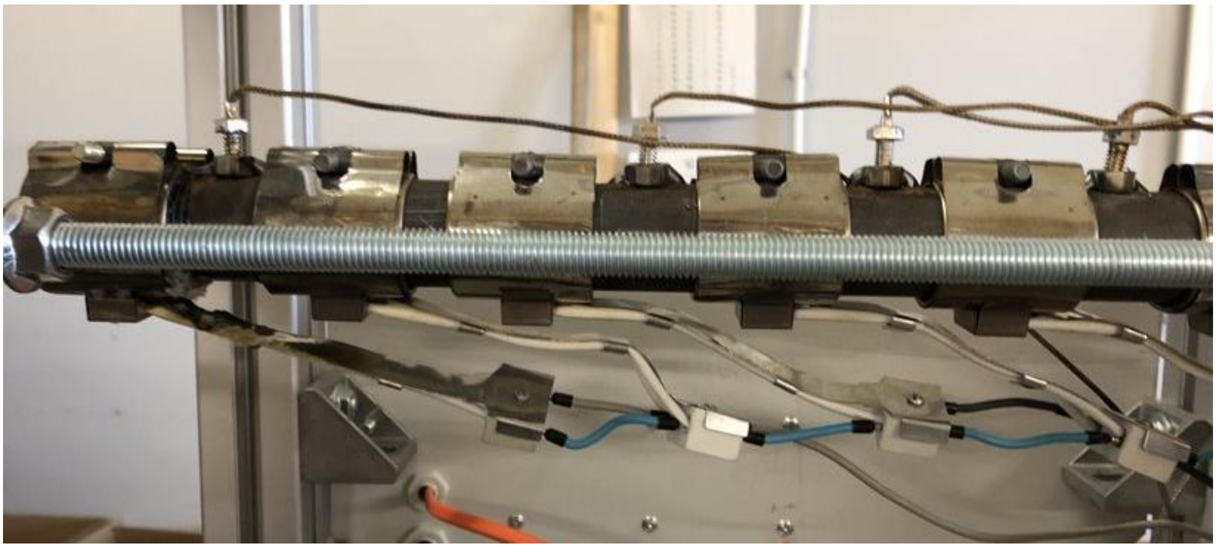


Figure 3 heating sleeves with the temperature sensors

03_clamp_mechanism

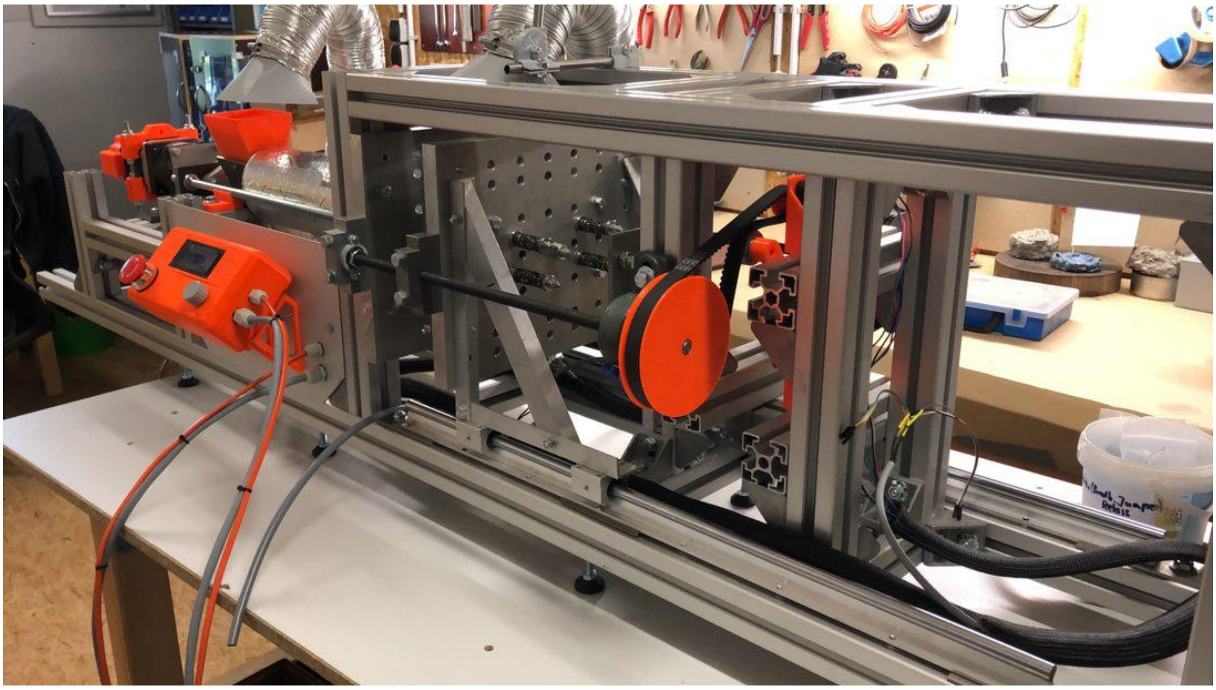


Figure 4 clamp mechanism overview

The clamp mechanism is the most crucial part when it comes to the complexity of the machine. It is more complex than the extruder and is rather a bit overengineered^^. The system is symmetric, so it is enough to explain just one side in detail.

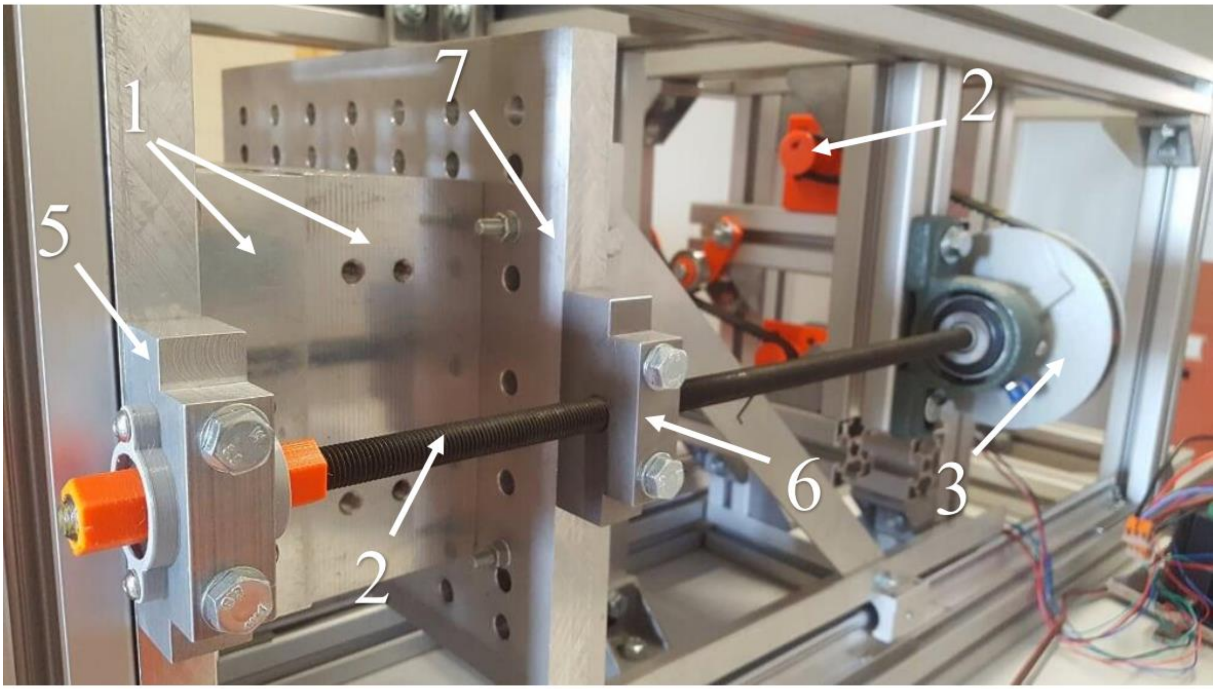


Figure 5 clamp mechanism detail left side

The thread (6-2) is rotated by a NEMA17 Stepper motor (also 6-2, sorry for the wrong numbering). The tooth belt in use is a HTD 5M-600. Both pulleys are printed out of PETG. The small tooth belt pulley is mounted to the NEMA17 shaft (6-2). The torque from the NEMA17 is transmitted through a screw in the small tooth belt pulley and a nut inside of it. The ratio of transmission is 1:3. So the torque in the thread is 3 times higher than at the NEMA17 shaft. Now it takes one full rotation of the big tooth belt pulley(6-3) to move the movable platen (6-7) linear for 1.5 mm (that is due to the thread pitch). The linear movement is created through the M12 x 1.5 thread in component 6-6. The system has a floating bearing next to the big pulley and a fixed bearing (6-5) mounted to the fixed platen. In figure 6 the mould (6-1) is completely closed.

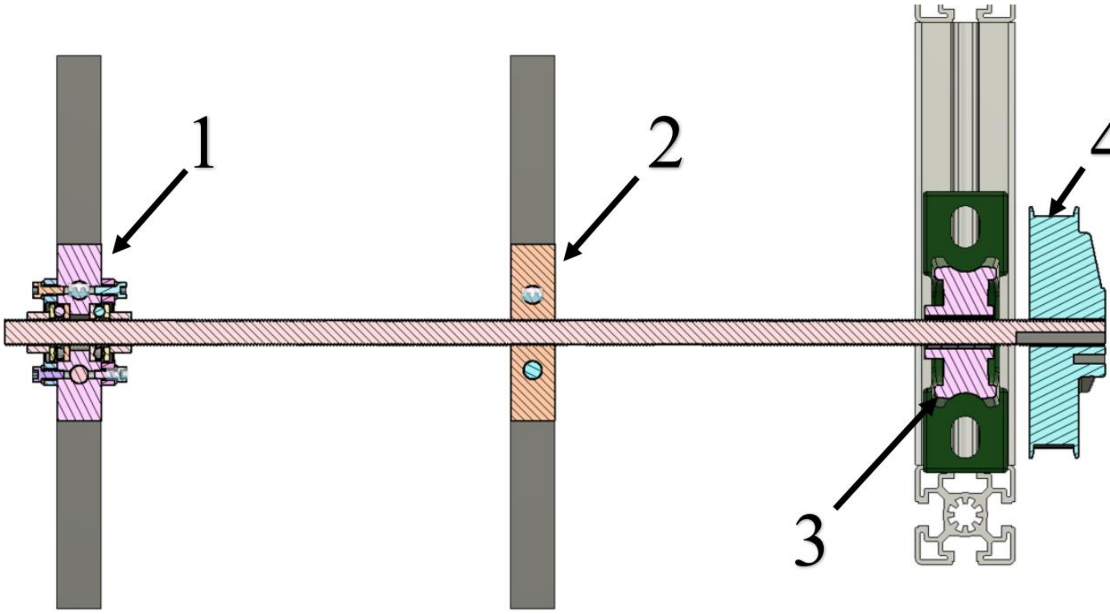


Figure 6 Section analysis of the clamp mechanism

The UCP bearing (7-3) receives most of the radial force in the system. When both mould sides get into contact, an axial stress (the clamping force) gets applied between the bearing block (7-1) and the thread block (7-2). 7-4 shows the big tooth belt pulley. The force applied on the pulley is one of the factors that determines the clamping force in the system. It is also important to lubricate the thread well, for having a better friction factor and higher clamping force.

For ejecting a finished part, we use a mechanism with 4 springs and 4 pistons, that are pushed out to eject a phone cover. This mechanism will be different with every mould and every product you produce. That is why we will not talk about it more in detail. If you are still interested in seeing pictures of it, check out the **Additional_pictures** folder.

04_ventilation_system

Since the heated plastic creates a lot of undesired fumes, a good ventilation system is necessary. The one built in the machine is quite powerful. It has a throughput of air of 500m^3/h. The fumes are extracted by the two extractor hoods located near the mould (ventilation mould) and near the hopper (ventilation extruder). With these two sections all fumes get extracted very well. Pictures in folder **Additional_pictures**. Both tubes coming from the hood are connected behind the machine. All parts here (except the small 10 mm pipes and the screws) are 3d printed.

05_mounting_limitswitch

For referencing the position of the movable platen, limit switches are used. One is triggered short before the mould is completely closed. If then triggered, the steppers do a certain amount of rotations. When the mould closes the steppers cannot turn any further. They then go to their torque limits and cannot rotate freely for some steps. This is also something to work on cause it's not healthy for the lifespan of the motors. The limit switches are normally closed. Thus, the system is hardware safe and will not try to close the mould endlessly if the switch circuit is broken. Pictures of this system are in the **Additional_pictures** folder.

06_user_panel

For controlling the machine, we created a user panel (blueprint **06_user_panel**). It contains 4 knobs, which are used for different functions. While using we found out that four different actions are enough to control the whole machine. After the parameters (rotations forward, rotations backward, delay time before opening...) are programmed and flashed, the machine starts by simply pushing the first button. It runs the program then once. Pushing button two makes the extrusion screw turn backwards for a predefined amount of steps(we need this sometimes when the nozzle clogs cause it releases the pressure in the nozzle), button 3 opens the mould manually and button 4 closes the mould manually.

The housing consists of PETG and is completely 3d printed (except the screws for sure). The LCD was in use, but we had problems with it always when we turned on the heating sleeves. This is also something to work on. The emergency switch opens the circuit. So, if pressed, the motors stop, and nothing can continue moving.

This user panel also needs a slight upgrade. It is hard to screw the plate that holds the buttons properly and to screw the plate with the cable mountings. It's not one of the big problems, it just takes some more iterations until it is simplified enough.

07_electronics

From the electronic point of view, there are three sectors of the machine. Those are the **motors** which make the machine move, **heating elements** that heat the granule and the mould and **sensors** to make the system run automatically.

In the electronics folder is a detailed circuit plan. We also attached pictures of the switch box. Many components inside the switch box have a printed mounting system. This is nothing that should be replicated 😊 It is ok for prototyping, but not safe on the long term. The specific components and some short information is listed in the BOM. The switch cabinet is mounted to the aluminum frame. This makes the whole system very compact and you have one rigid machine.

08_program

In the folder program we added a VS "sketch". The program is very primitive and for sure just something to test the machine with. Any programmer can do this way better than we did, so if you decide to write an Arduino sketch for the machine on your own, please share it back 😊. We would love to see your solutions.

For programming the Arduino, we used the Arduino extension (Visual Micro) for Visual Studio. The program has several functions, which are activated when a button gets pressed. Before flashing, the parameters at the beginning of the main file must be set in a fitting way (fitting to the part you inject). If the volume is smaller you need less rotations and if bigger you need more. Pretty simple 😊.

Troubleshooting

Below are the problems, that we still have with the machine. If you find good solutions for them, please let us and everyone know. We also work on them and none of them are big problems, but there is almost always a way to make things easier. Sharing is caring 😊

Clamping force:

The force needed to hold the mould together should be higher. We calculated a force of around 9000 N when the stepper motors go to their maximum. Before that we screwed the mould manually with 4 x M10 screws. These M10 screws created a clamping force which was approximately 12 times higher (4 x 26 000 N).

The mechanism could be improved either with stronger motors or with bigger threads. To make the machine better in clamping, it could be just more rigid. Then the threads would deform less, and the mould would not open this much. It uses to open around 0.8 mm, which then also makes the phone covers thicker.

Clogging of the nozzle:

After a phone cover is successfully injected, the sprue should come out together with the phone cover. Then all the solid parts are removed from the mould and the tip of the nozzle. This is not properly working so far. After every shot we must be sure that the mould tip is free. Otherwise there cannot be the next part injected. The problem causing this effect is rather easy to solve. After we ran some thermal simulations in Fusion360 on the nozzle and the way it is mounted, we found out that through the huge contact surface with the stationary platen (made out of aluminum) it cools down too far. So, to fix this there must be a hole, that is big enough to fit the whole nozzle in without touching it. Then the nozzles tip can simply be mounted directly to the mould, which will prevent the huge loss of heat.

Synchronization of the Steppers:

With two separate motors there is always a synchronization problem. If one stepper is blocked for even just one rotation of the shaft, it ends up in a small angle of the moulds surfaces when being closed.

As solution we observe the synchronous movement of the big pulleys with two hall sensors and small magnets attached to the pulley. For a next version of the machine a solution with only one actuator would be much better. A toggle system for example. It is something we want to work on 😊.

Software:

As already mentioned in 08_program, we are no software developers or anything near to that. So, there can be a lot of improvement done with it. The program parameters should also be changeable from outside the program. Flashing the Controller new every time when you tune a parameter is pretty inefficient and can also be a source of problems.

Tips and tricks

CAD

if you do not use a CAD software yet, we highly recommend Autodesk Fusion360. If you are in an educational program it is for free. The program is extremely powerful, and you can do constructions, blueprints, simulations and so on. We are not getting any benefit for saying this btw :D . We would have saved a lot of money and time if we had known this software and the possibilities better from the start 😊.

Parts for 3d printing

we did not add STL files to the CAD folder. But it is easy to export STL files from the STEP CAD files we added. There are videos about how to do that on the YouTube 😊.

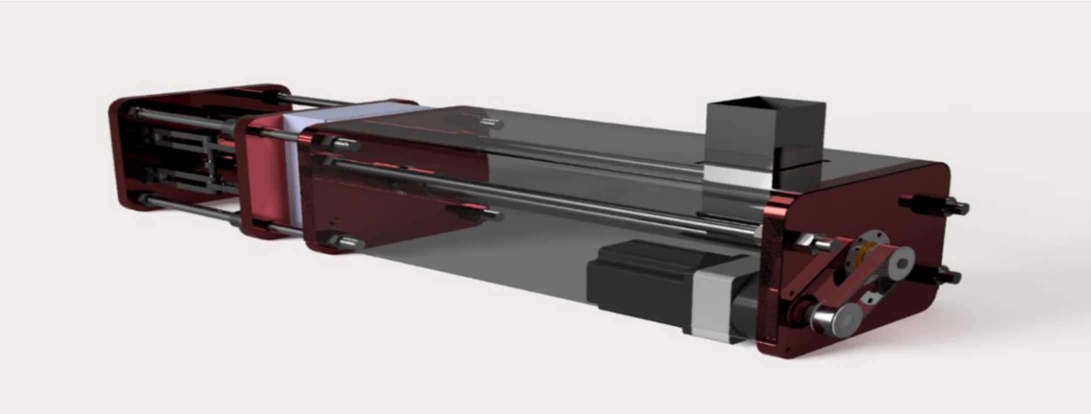
Threads in 3d printed parts

A cool hack for making threads in 3d printed parts is printing the wished thread just as a hole with the core diameter. After it is printed you just cut the thread like you would cut it into metal. These threads are not very strong, but they fit most purposes 😊. Just in case you wonder why some parts in the user_panel and the bodies of the mounting_limitswitches do not have threads, we used this trick there.

Next steps

Some CAD is already newer than the stuff built into the machine. It is not tested yet, but it should only be a better version 😊. Especially the 3d printed parts. Testing these is part of the next steps. Furthermore, it is our plan to make the functionality of the machine better. It needs to run fully automatic and with decent quality to really make a big difference in production. This is what we will focus on for the next time.

When this step is done, we want to make the machine certified. Since there is a huge demand for decentralized plastic-recycling solutions, we want this machine to be available for almost everyone. But for now, there is only some sketches and ideas of how the certified version can look like.



Congratulations if you made it down until here. We are super happy to share this knowledge with you and even happier that some people can use it for solving recycling problems.

Me (Manuel, 22) and Benni, 23 are two engineering students from Baden-Württemberg, Germany. Benni worked before as Electrician and I worked as mechanic. We did not get the knowledge needed to build this machine only from our studies (what we knew from our work and some online research was enough already), so don't be scared of the task if you don't study mechanical engineering or something similar 😊.

We hope this information helped you out. If you're enthusiastic and interested in plastic recycling, we challenge you to join a project in your region. If they do not exist yet? Create your own! It was never more important than now that creators and engineers tackle these problems. You will not stay alone for long with your great ideas, that is for sure 😊 We can't wait to see your project.

If you like what we do and you feel like it is worth a tiny tip, then you can scan the QR-Code from our PayPal and support us with some cents😊. We are happy for every help that we get for developing these machines.

Cheers,

Manuel from SOTOP-Recycling