Lessons learnt and failures throughout the Pedal Power Project 2016/2017

Scope of the project was to design and construct a low-tech pedal powered shredder for polyethylene terephthalate (PET) plastic bottles and one for garden compost. In general, we had to accept, that trying to construct both systems at once proved to be rather difficult.

Plastic Shredder

Cutting device

An intensive research indicated, that a solution without using computer numerical control (CNC) machine tools would not be possible regarding the plastic shredder. All successful attempts used the same sort of cutting device made of steel with small hook like edges to tear the plastic apart (see picture). Other constructions cutting bottles only worked for one bottle at time and thus would not provide a sufficient solution to shred larger amounts of plastic waste. Our idea to build the cutting device by 3D printing was rejected after an evaluation with a producer of filament. The cutting edges need to be stronger than the material that is supposed to be decomposed. Using plastic to work on plastic is this unlikely to work out. Also, the 3D printing is limited in stability of the layers printed on each other. Judged on by people working with 3D printing, it would have been highly likely, that printed blades would tear apart throughout the process of shredding. As our aim was not to work with high tech equipment such as CNC machines, we evaluated whether constructing the blades would be possible in another way. According to the judgment of metal working professionals, whom we consulted, it is difficult to achieve sufficient accuracy with alternative techniques, such as forging and/or using an angle grinder.

Material

Despite the problems regarding the construction of a cutting device, we also found out, that there will be various difficulties related to creating a product other than just thermal energy out of the old PET bottles. Ideas considered for recycling include: Filament for 3D printing, raw material for new fabrics in the textile production, building (construction) material. As for the filament and textiles, both need very clean and defined raw materials whereas it is not possible to use mixtures of different plastics. The production of filament out of recycled material already gets compromised by tiny fractions of the ‘wrong’ material. Considering this, there would be a need to further process the material collected (correctly sorted, cleaned etc) which most likely would be easier with complete bottles instead of already shredded materials. To create such a homogeneous product for the use as filament within a low-tech environment is rather unlikely. The same problem of need of clean material occurs regarding the use of recycled material for fabric fibers. Options of thermal/energy use have not been considered.

Considering these two major obstacles related to producibility and use of the actual product of PET-shredding, we decided to focus on the garden shredder first and to postpone works related to shredding plastic. Our expectation still is, that the gear for both will be quite similar. Thus, by establishing a sufficient one for compost material, only the cutting device will have to be changed later to use the system for plastic materials. The question of further use of the shredded plastic material remains. Within our time frame of initially 4 month (extended to 7 month) we were not able to finalize the PET system. By the end of the project, we decided to order one set of prefabricated blades (CNC). Anchoring in a community of makers being interested in shredders, and organized via the forum of the precious plastic project (https://preciousplastic.com/en/), we had the chance to join a group order of CNC blades, which reduced the price for one set drastically. The task of assembling the prefabricated parts and connecting them with the pedal-power device, will be continued in summer 2017 by a students' project at Technische Universität (TU) Berlin

Garden Shredder

A review on existing pedal powered shredding devices for garden material, showed us, that there is a variety of individually designed systems. Unfortunately, most of them did not include information about the size of material that can be cut with the specific set up. Also, the transformation of power from bike to cutting device was rather poorly described in many cases. We found several pictures as well as lists of components use, but actual information about the interconnection was not always given.

2.1. Shredding device

Shredders run by electricity either use a knife with high rotation speed to cut branches etc. into pieces or they work with less revolutions per minute (RPM) and work more like a drum, using pressure to break and tear the material. An overview of common cutting devices for garden shredders can be found in the table below

	Knifeshredder	Drumshredder
		 
Power	2000 W	2.500-2.800 W
Rotation	3000-4000 RPM	40 RPM
Torque	14 Nm	600-650 Nm
Advantages	Low price	Silent
Disadvantages	Loud, gets easily clogged, high maintenance need	Clogging with wet material, hard to
Suitable	Rather for mulch than compost due to shredding process	Output in chunks, convenient for compost
Capacity	ca. 90 kg h-1	175-230 kg h-1

Table 1: Common principles of shredding

One limitation using a pedal powered device is the power possibly produced by a human on a bicycle. An average rotation of 60 RPM and 100 – 150 watts can be assumed. This power output does set the frame conditions for what can be achieved by a pedal powered machine.

To get a better understanding of the shredding process, we dissembled a standard garden shredder (knife version) and discussed the issue possible Designs with various persons regarding blade construction. Looking at the power consumed by commercially available systems, it became quite clear,

Figure 1: Assembly of driving gear to the mower

that the pedal powered version would only be suitable for garden waste up to a certain limited size and strength. Cutting branches would already be difficult.

In addition to the common commercial devices one can find in German (or European) stores, we also were able to look back at personal experiences made with a shredding device built in Tanzania out of old machetes to cut banana leaves.

Finally, we decided for using an old hand mower as cutting body for our system. The shaft of the mower has been used to mount a chain ring which can be connected to the bicycle by a regular bike chain. We made several different attempts on how to mount the chain ring on the mover. Our first approach was to weld a plate and socket to the chain ring and connect these with the shaft of the mower. Depending on the material available, there might be problems in connecting them with each other (Aluminum). Also, to actually keep the chain ring in a centered and orthogonal position towards the shaft of the mower, was difficult. After several different attempts, all including some welding, we decided to use a crank with attached chain ring. By cutting threads into the shaft of the mower, we created the option of a screw connection. This allowed to mount the chain ring quite centered with an easy way of changing the gearing if necessary through exchanging the chain ring to one with more or less teeth.

2.2. Transition set up

2.2.1. Version 1

Regarding the different systems used for power transmission by pedal powered devices, we first chose to use a set up published by “Technology for the Poor” (Figure 2). This “Dual Purpose Bike” has been used for several applications such as nut shelling, pumping and sawing. One advantage is, that the bike remains drivable and thus can easily be transported. Our adaption of the system is shown Figure 3. It is recommended to use a small flywheel in this system to even out the power transmission. Our solution to this was to use a lifting weight as they are usually easy to find and already have a centered hole which can be used for further assembly.

Figure 2: Dual Purpose Bike by Technology for the Poor [Ebenezer, 2017]

Figure 3: First version of power transmission

As for the bike stand, we chose a design similar to the one provided by “Technology for the poor”, which has been used in our approaches and proved to be a good solution. The bike stand is welded and can be pulled up as a bike rack. Once on the ground, it stabilizes the bike but still allows to keep the spinning function of a bicycle.

Results: The system was hard to set up as the information provided by “Technology for the poor” are not complete and many parts for the construction had to be adjusted to the specific bike. We used a bottom bracket as center piece and mounted a sprocket on each side. Doing this is accompanied by the problem of “how to keep the hole thing (transition piece) centered?”. We tried different solutions, always using the threads of the bottom bracket to connect the various pieces. Our experience with the set up was, that there were too many small inaccuracies all adding up to instability. The chain path needs to be rather straight in order to be kept on the chain ring of the mower. We were not able to achieve such a straight line with the design. This led to constant drops of the chain causing not only malfunction of the shredder but also possible danger to people standing next to it. As our aim was a low-tech solution, we figured that

if we were not able to construct the transmission in a well-equipped workshop environment, this would not serve as solution for our shredder.

2.2.2. Version 2

After discarding the first design, we came back to an initial idea based on the systems of Maya Pedal (http://www.mayapedal.org/). For heavy duty work, they usually use a concrete flywheel. Again, the construction manuals to be found left many questions and we came up with our own version on how to build the concrete wheel. Here, the idea is, that a second sprocket is mounted to the wheel. Once someone is pedaling using the normal chain connection, the sprocket on the other side of the wheel also gets moved. From there, a second chain is attached and connected to the mower. As we had to find out, that this set up still left some problems, we will not give detailed description on how we connected the second sprocket to the flywheel. Our version is shown in the following picture.

Figure 4: Concrete Flywheel

Conclusion: The system worked better than the first design, still creating several problems. The flywheel is rather heavy and not well to handle. To mount it in the bike instead of the regular wheel is rather complicated. Also, transportation is an issue. The flywheel did allow to shred some material but once the shredder blocks, the wheel can still be in motion. In this case, the transmission from bike to shredder continues but the power created cannot be transferred. As a result, either the chain springs of, or something must break. A solution for this problem could be the use of a freewheel drive instead of a fixed sprocket. However, on the one hand this created problems in terms of space available at the bike and on the other, the obvious advantage of a flywheel, which is using inertial forces of a moving mass to stabilize the transmission to the shredder, is no longer realized. Due to this, we did test, whether it would be possible to run the shredder of the sprocket cartridge on the original wheel of the bike.

2.2.3. Version 3

In our final version, we used the same sprocket cartridge to set the bike wheel into motion and to drive the shredder. This direct way of transmission proved to be the best option for the shredder after conducting a trial series for testing the concrete flywheel in comparison to using a regular bike wheel.

Conclusion: There was no significant difference in between the performance with/without flywheel. Regarding the handling of the system, the set up without flywheel has the advantage of easier assembly and less parts necessary for the construction of the whole set up.

How does it finally work:

We mounted the mower on to an old bike trailer and created the option to connect this with the bike stand. Not only does this provide a fixed distance in between the sprocket of the bike and the chain ring of the mower, but it also allows to keep tension on the chain.

While the bike gets pedaled, the regular bike chain is sitting on one of the smaller sprockets. At the same time, the chain connecting the bike to the shredder is located on one of the larger sprockets so both chains can not interfere. While the person on the bike is pedaling, the shredder also is set into motion and can start to work. If there is an obstacle in the shredder and the blades block, the chain stops spinning. Due to the freewheel, this does not result in tearing anything apart.