Design of Machines and Structures, Vol. 8, No. 2 (2018), pp. 19–29.
https://doi.org/10.32972/dms.2018.009

BIODEGRADABLE TOOTHBRUSH

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Abstract: During our third year we took part in an international project called Heibus project (https://www.linkedin.com/company/heibus-project). We got a topic according to which we had to work. This topic was biodegradable products. The next article is about these products and about how these products are developed. If you are in the habit of reading what supermarkets print on their plastic bags, you may have noticed a lot of eco-friendly statements appearing over the last few years. We followed this idea through our project as we designed and developed, eco-friendly products, as alternative to disposable polymeric products, that have a high impact on nature. We tried to reduce the environmental footprint through the development of new and biodegradable plastic products.

Keywords: *biodegradable, polymer, toothbrush, 3D printing, FEM*

1. BRAINSTORMING

For this matter we had to consider all the different fields where people use too much non-biodegradable items.

As we looked at all the different fields, which was not easy considering humans have a way of producing too much unnecessary products that can become trash over time.

One of the most effective ways of collecting ideas is brainstorming. It is a form of collecting new ideas, everything that comes to one's mind. There are no bad ideas in this stage of the gathering. We just wrote down everything that was considered useable for us. We looked at separate areas.

The first area was the Medical field. We could see many opportunities here though this is a very difficult matter to work with. We could list stitches, prosthetics, plasters, metal plates, arch supporters and spine corsets as interesting products to work with.

The second area we looked into was sports and games. We could think of mouthguard, safety garment, inflatable toys, wheels, plastic bottles and fishing tools to consider. This area looked more realistic for us.

Our third area was gardening, because as we were going through some books, we realized that many gardening techniques include leaving rubbish behind. So, we were thinking what if we can replace those items that accidently stay in the soil with biodegradable ones. This led us to think about watering tubes, watering cans, chairs, tables and different containers like underground containers.

The forth fields was full of opportunities. We looked at bathroom accessories and we discovered that tons of trash is piled up from almost every product found in bathrooms. Toothbrush, comb, razor, shampoo bottles was just some of the things we have found we could replace.

Kitchen tools were something many companies were already dealing with, including the Andaltec which is a non-governmental organization, so even though we found many things to works with like fork, knife, spoon, pet bottles, caps, plastic glasses, six packs, food containers and even egg holders we did not really see big opportunities here as these products are already being replaced.

We found random everyday tools we came across with, like plastic phone cases, cables, distributors, eye/sun glasses and their cases, keychains, ID folders and umbrellas.

Stationery products were also something to take into consideration. We could meet with plastic pens, highlighters, computer mice, plastic folders, keyboards and fans, but these items are used for a considerably long time, so these were eventually out of the question.

Other product we have found were traffic navigating tools, night time lamps, lamp shells. One really interesting idea was to replace festival grounds. Every summer when festivals come, there is a huge amount of rubbish after the events, but what if we could change some of the rubbish into biodegradable ones. Those paths they use against mud and rain are often made from plastic that cannot degrade, but if we replace those we could save some valuable amount. We only need those during the warm seasons, so it would be great considering the time of the degradation.

Last, but not least, we looked at our beloved little pets. We could also find many items that are replaced almost every year or so, like toys, plates, litter strays and poop collectors.

Other really great idea was to make biodegradable diapers since they are used so often (children, adults) and there is a great amount of trash from them, but as we search the market we discovered that these are already being made in several countries, so we could not follow this path either.

These were our first ideas we gathered and then we reduced them. *Figure 1* illustrates these possibilities.

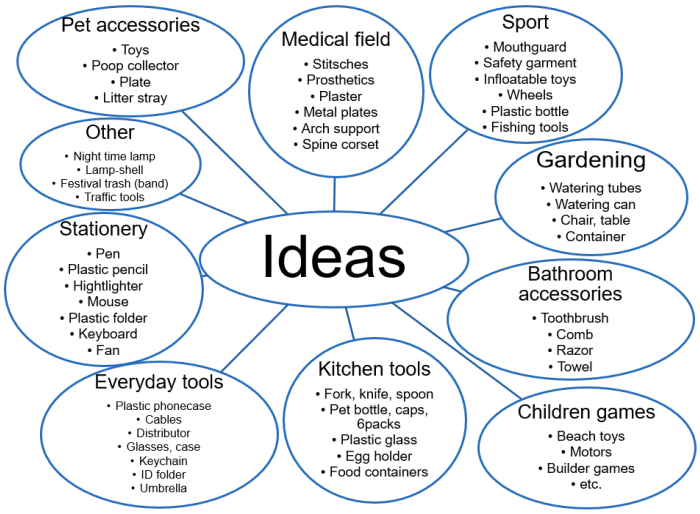


Figure 1. Brainstorming

2. CONSIDERED PRODUCT POSSIBILITIES

After long consideration we settled with bathroom accessories because we felt that this is a great field to work with. We collected all the tools we could imagine manufacturing from biodegradable polymer. We came across the next things:

- toothbrush
- toothpaste container
- floss container
- razor
- band aid
- cup
- comb
- shower cap
- shampoo bottle
- little traveling bottles

After taking all to consideration we decided to go on with designing a toothbrush. This seemed like the best option looking at environmental effects, designing, manufacturing and marketing.

Other products like combs would have had problem with designing and also manufacturing, beside they are not thrown away soon enough to make them out of biodegradable materials.

Band aids are a good idea, but we would have some problems with the sticking part and also the design cannot really change from the basics.

3. MARKET RESEARCH

Bogobrush is a biodegradable bamboo toothbrush. It has a simple, clean design and great colour choices. The bamboo colour is combined with turquoise, white and fresh green. These colours complete the design making the feeling of the toothbrush even more natural. Not only the handle is coloured but the brush too.



Figure 2. Market research I

We can see a closable toothbrush in *Figure 2*. It can be practical when traveling or if we are lack of place. The design does not look so nice and also the ergonomic aspect is not really great. The handle cannot be too comfortable. The green toothbrush is a concept design. It illustrates how they want to wash the teeth from every side. We are not sure about the function's potential as this one is just a concept.

We also found a closable toothbrush with a replacable head. This in *Figure 3* is closer to our thinking but the design and closability is still poor here. Next to it, there is a really practical toothbrush with a closing part. It is quite simple, but the texture is nice and the plus function that you can put it on the wall, makes the toothbrush one to look at.



Figure 3. Market research II

In *Figure 4* we can see some toothbrush concept sketches and a new concept next to them. This considerably big toothbrush has a unique function that has never been seen before. It works like a roly-poly toy as it has weight placed in the bottom, so it is always standing.



Figure 4. Market research III

Our other competition can be seen in *Figure 5*. Although it is bio, it looks quite casual, with nothing special or mentionable. It has the wood like texture and that is

all we can say about this product. Beside it, we can find a toothbrush with toothpaste in the bottom. The concept is that you can turn the bottom and as a result the toothpaste goes up to the top and you can brush your teeth, but this concept never made it to the stores because of the many difficulties, which appeared during testing.



Figure 5. Market research IV

4. CRITERIA SYSTEM

Our product is dedicated to all the people. It is an everyday common product so we cannot define one type or group of people, because everyone can use it.

Our original product was designed for adults, but since it has a replaceable head, we are planning to design one head for children as well with smaller brush and head.

Environment of our toothbrush:
We are designing it to any kind of environment where people are acceptant about it. We do not want to make a luxury product that only rich people can buy, we rather want to aim at larger layers of people, as a result our price should be reasonable.

Selected functions:
- toothbrush
- replaceable head
- biodegradable material
  (further innovations: razor head, brush for braces, children brush head)

5. SKETCHES, DIFFERENT CONCEPTS

We came up with several different concepts during our project. These sketches were drawn on paper, so we scanned everything. In *Figure 6* our thinking can be followed.

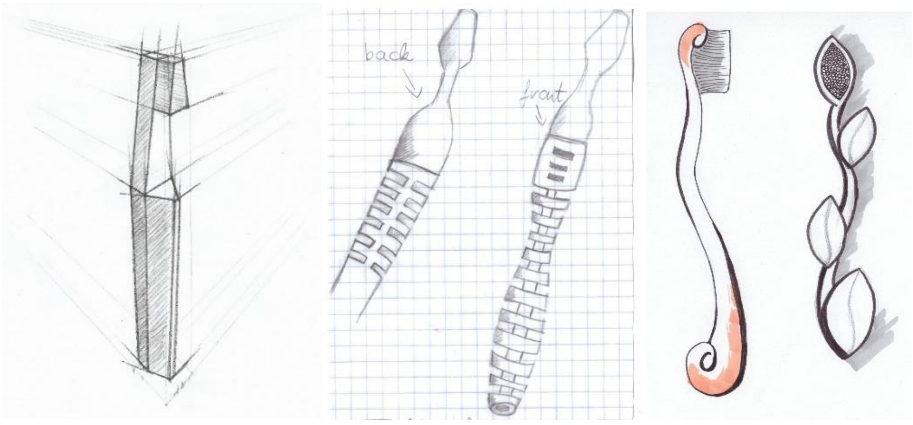


Figure 6. Hand drawn sketches

5.1. Searching 3D designs

We wanted to know how exactly 3D printed products are made and designed, so we looked up some 3D printed designs as inspiration to our designs. We came across quite a few of them, used in many fields. From printed prosthetics to toys, casts, statues and so on.

As this area (3D printing) is a considerably new field comparing to steel works or pottery, we tried to look at the aspects that makes this technique unique and different from the others. Finally, the big realization was that 3D printing methods can use less material with only printing the structure of the products. Once we set our minds on this concept it was the path to go on. In *Figure 7* it can be seen what we were referring to earlier.

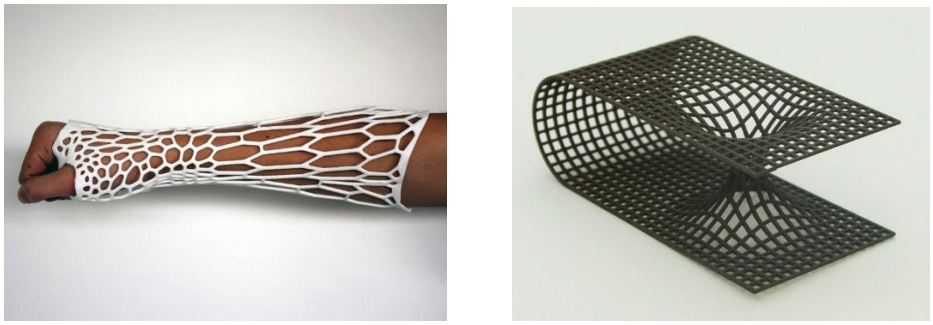


Figure 7. "Gap" designs

5.2. The "gap" design-Solid Edge models

As we were going through the designs, it was clear that it must be a simple one, because the injection part can only work with two sided designs, so we cannot put design all around the handle but only from two sides. This way it is possible to print

the design and also possible to inject it. After we considered the cut-out part's design we started to work on the 3D model and design.



Figure 8. Solid Edge design

5.3. Final design

The original design was suited for 3D printing, but it would have many difficulties with the manufacturing using injection, so we had to change the design to a simpler one.

Figure 9 shows how the printable and injectable model looks like.

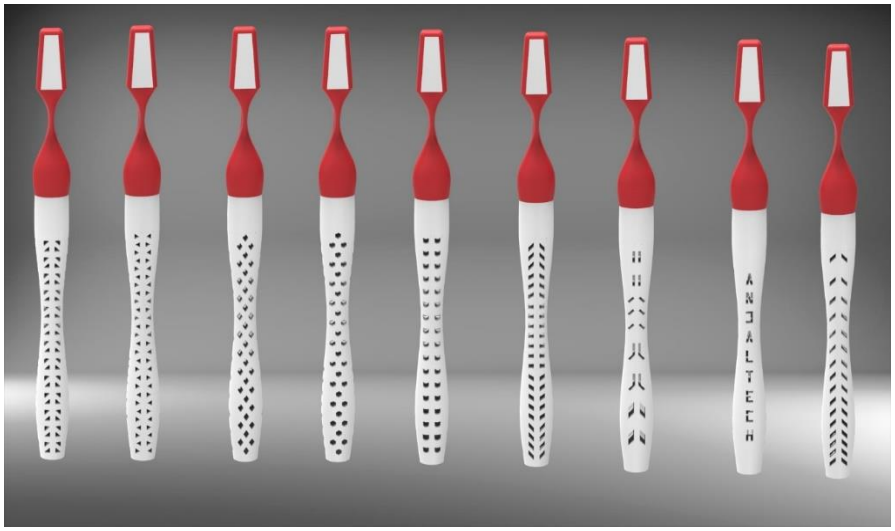


Figure 9. Solid Edge desings

6. FINITE ELEMENT METHOD

We ran a finite element method analysis on our product, so we could measure its mechanical attributes and deformations. We ran three different kind of analysis with different forces and fixed supports.

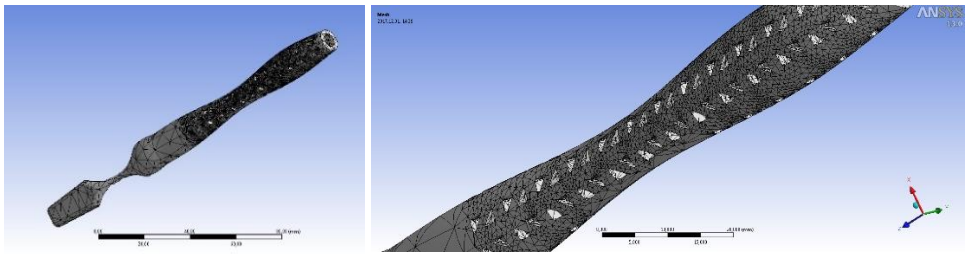


Figure 10. FEM mess

For our first analysis we had to import our item into the Ansys program, which we used for the analysis. The mesh of the product was quite complex, so it took some time to import and to make it. We added the pictures of our progress all through the way. In the first case we put a fixed support on the end of the handle and we put a 10 N force on the head. The corners showed the largest deformation, but even that was not dangerous to consider it.

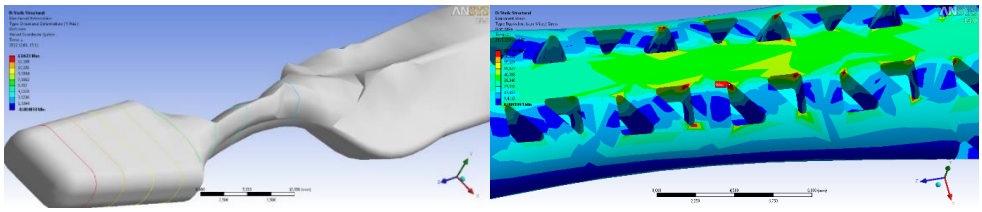


Figure 11. FEM I

For the second simulation we changed it up and put the fixed support on the head. We also put 10 N force on the body of the toothbrush. As it was expected, the toothbrush bended, but it was also eligible to work with.

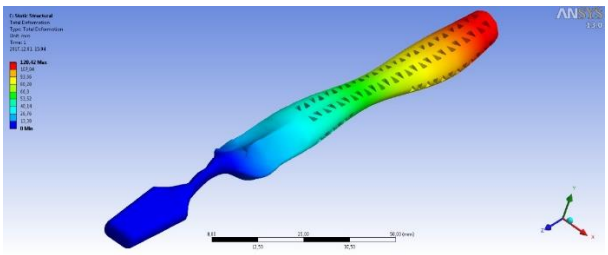


Figure 12. FEM II

For the third simulation we changed it up and put the fixed support on the head. We also put 10 N force on the body of the toothbrush. As it was also expected in this case, the neck gets the most stress from the deformation. We analysed the results and we found them suitable for our product, so the manufacturing process could continue.

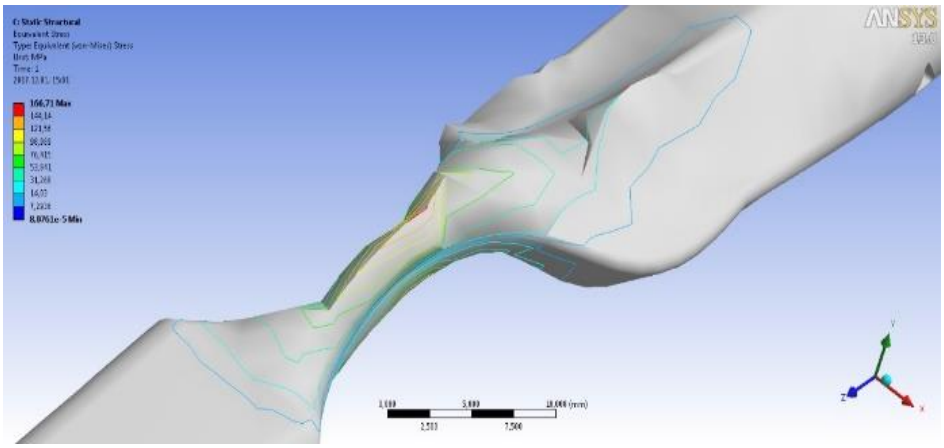


Figure 13. FEM III

7. PROTOTYPE

The "gap" design prototype:
We printed our prototype in the laboratory of the University of Miskolc in the Institute of Machine and Product Design. In a few days we could hold our prototype in our hands. It was printed with a one extruder printing machine, in laying down position. It took 3 hours and 42 minutes to print the toothbrush. The prototype is made out of our chosen material, biodegradable polyactic acid, PLA. It weighs 13 grams.

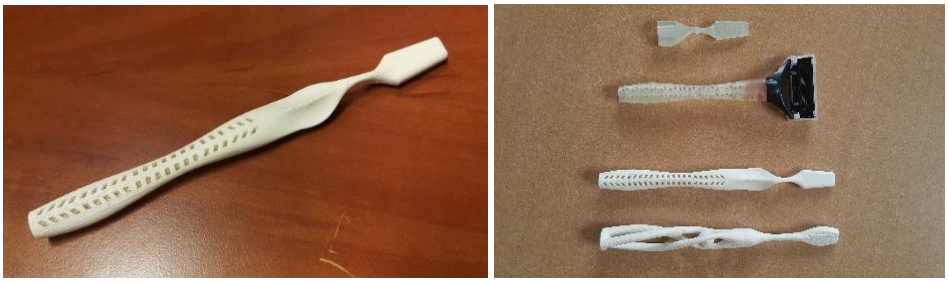


Figure 14. First prototype, other printed concepts

7.1. Additional ideas, future ideas

Other ideas were replaceable heads with different functions. We can design a razor head and use the handle for that razor head also. We could make a kid's toothbrush head since they need a smaller head and brush. We can also make a special brush for braces as an additional plus function. These are some future ideas to work with.

If there will be some different heads to the handle it will probably need a special stand for it and for the heads. The concepts in *Figure 15* show these possibilities.



Figure 15. Other accessories

7.2. Plus design idea

As an additional idea a special shaped toothbrush was also designed. This one has a unique structure, but its manufacturing is a different story. The printing process can work with multiple head printer, but the injection process is not possible at the moment for this design. It is noticeable that the white concept refers to teeth if we look up closely and we have a little imagination.

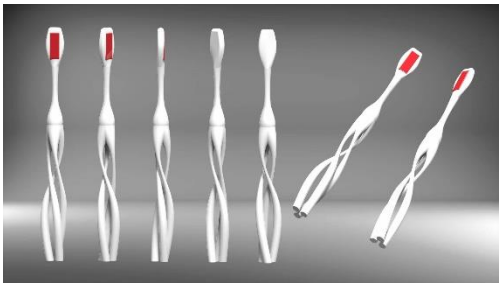


Figure 16. Tooth-like concept

8. ECOLOGICAL FOOTPRINT, LIFECYCLE

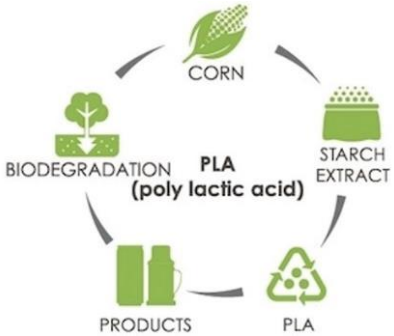


Figure 17. Lifecycle

It can be seen in *Figure 17* that opposite to the usually used plastic and nylon it can be composed. The plastic and nylon that make up the handle and bristles of your toothbrush both come from petroleum, a non-renewable resource with a long list of negative environmental impacts. Manufacturing nylon not only creates nitrous oxide, a greenhouse gas 310 times more potent than carbon dioxide, but it is an energy and water intensive process that results in runoff. Although it is difficult to get away from the nylon bristles, alternatives do exist. (from internet statistics-https://www.huffingtonpost.com/rosaly-byrd/the-environmental-footpri_b_5699007.html)

These sentences prove that toothbrush makes a valuable argument when talking about replacing an item with biodegradable polymer.

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