DESIGN FOR THE URBAN MINE

Utilizing high purity reycled monostreams from household plastic waste for injection moulding

Graduation Project
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ABSTRACT

Keywords; plastic, recycling, high purity monostreams, PP, injection moulding, 3d printed mould,

Plastic is a material that has greatly improved well being for the masses. However, it also contributes significantly to pollution of the natural environment and depletion of natural resources. So far only a small percentage of plastic is recycled and used for the production of new products. Inferior material quality and the inability to make a profit out of plastic recycling has led to little development in the utilization of this material. Umincorp is a company that developed a separation technique called magnetic density separation. With this technology they aim to make a profit from recycling and deliver high purity monostreams that can be used for a wide range of applications. This report describes the process of the development of a showcase product for Umincorp. The product aims to convince designers and producers of injection mould products, that Umincorp's material can be used as a valuable resource for mass production.

The research creates an understanding of what value this high purity material has to offer and what role designers and producers play when trying to increase the demand for this material. Next to injection moulding; rotomoulding, blowmoulding and extrusion are looked into to find opportunities to utilize the recycled flakes directly. Injection moulding was found to be the most accessible production method for processing the recycled flakes. The production of keychains in an existing mould using recycled PP was an important part of this conclusion. The choice for production in a 3d printed mould at the company P3d was made to establish a product design and production within limited time and costs. 3 concept proposals were made for products that could be presented in the context of a business fair. A business cardholder that can also be used as a nametag in multiple ways was chosen as the final product. It gives multiple qualitative examples of injection mould features, aesthetic and mechanical properties. It was produced with 99+% purity recycled PP flakes from household waste with 6 different colour separated batches.

P3d noted that the material can be processed without complications. Unfortunately, the cardholder's geometry was a bigger challenge to produce in the 3d printed mould than was expected. This resulted in an early failure of the mould, leaving only 14 products that are unable to close because of unusable clickfingers. The surface quality of the products do not show much imperfections and 6 different colours were obtained. 4 interviews were conducted with developers of injection moulded products to come to the final conclusions for the results of this project. It shows that the target group is partly convinced about the value of this material. Using the flakes directly for the production seems to surprise people when they see the surface quality of the products. The developed products seem to be a step forward in opening up the conversation about possibilities for recycled plastics from Umincorp. Next to these products, quantitative data should be available in the form of reliable data sheets and test samples in order to take away more insecurities from designers and producers of plastic products.

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GLOSSARY

Urban Mining Corp / Umincorp
The company that gave the assignment for this project. Urban Mining Corp recently started using Umincorp as their official name.

Monostreams
Material batches with only 1 type of plastic.

Post production vs Post consumer
The monostreams that Umincorp delivers comes from post consumer waste like household waste. Post production waste is excess material or outfall of products that occurs during production. The origin and specifications of this type of waste stream is easy to track unlike in post consumer waste were the input of material is mixed and originates from different sources.

Purity
Monostreams can still be contaminated with other plastics or materials. Umincorp can deliver monostreams with a purity of 99+% purity.

MDS Magnetic Density Separation
This is the separation technology Umincorp has developed and makes it possible to deliver a high purity monostream.

Virgin
Virgin plastic is newly made plastic.

Flakes
This is the output that umincorp delivers. It consists of small pieces of recycled shredded plastic.


plastic flakes

Granules
Granules are the common form in which virgin plastics are delivered.

Compounding
The process of composing new plastics and the addition of additives or turning recycled flakes into granules is called compounding.

Additives
Additives are added to the process of plastic production to obtain certain specific qualities like UV resistance or plasticizers.


plastic granules

MFI
Melt Flow Index is a measure of the ease of flow of the melt of a polymer.

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PROJECT CHOICE

I would like to start off by explaining my motivation for working on this specific project.

During the graduation project I wanted to work on a project that grasps my personal interest and helps to bring something useful to the world. Useful can mean many things. For me it means working towards a sustainable way of living on this planet as a modern society. Pollution of the natural environment and the resulting climate change has shown us we are facing severe problems in the near future. I worry about this and want to find out what product designers can do to help overcome these problems.

One of the things I love to do is surfing, either in the cold water of the North Sea or in some far away exotic place. Unfortunately you get confronted with plastic waste in a lot of these places. This was a trigger to work on a project that focuses on a material that, next to causing serious problems, has also opened up so many opportunities for us: Plastic!

Sincerely,

Jorn Meinderts

1.

INTRODUCTION

This first chapter starts of by introducing the assignment for this project. Problems surrounding plastic waste and production of plastics will be addressed and narrowed down to the topic of recycling. Umincorp is part of the recycling industry and provided the assignment for this project. An introduction of this company and their technology can be found here. Finally the approach for the assignment is explained that was used to work towards an end result.

CONTENT

1.1. PROJECT BRIEF

THE COMPANY

Urban Mining Corp is a spin-off company from the TU Delft, aiming to become a multi-billion corporation within the next generation. Their business: using advanced sorting & separation technology to produce new material streams from urban waste – hence, urban mining. Their current focus is on high-volume, low-cost plastics, mainly PE, PP and PS. Now that the technology has proven to work, the next task is to find meaningful, sustainable applications.

PROBLEM DEFINITION

Demand for recycled plastics is relatively low. Prices of recycled plastics are often higher than that of virgin, because of the relatively low oil prices and established techniques to create virgin plastics (Researchandmarkets, 2018). Another reason why the demand is low is because of the quality. Not fully optimised recycling techniques, pollution and mixed plastics result in a lower purity and thus less reliable plastic. Product brands and manufacturers fear that recycled plastics will not meet the needs for a reliable high volume supply of materials with constant quality specifications (EC, 2016).

Umincorp has developed an optimized recycling system that can deliver higher purity plastics for a lower price than before. Optimization of their material output is being developed further to be able to offer a more constant quality. This asks for a steady input of material and costumers who are willing to buy the output and use it for new products. So far there are no product designers within Umincorp. They would like to gain more insight from the perspective of product development when it comes to utilization of recycled material from household waste.

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ASSIGNMENT*

Umincorp wants to gain more insight from the perspective of utilizing their material for production of mass produced products by developing a product from their recycled household waste material. This product should act as a showcase product that helps to convince potential customers, that material obtained by MDS technology can be used as a valuable resource

* The orignial assignment by the company and the project brief from the kick off meeting can be found in Appendix 1.

1.2 THE PROBLEM WITH PLASTIC

Production of plastic is made possible by the use of fossil fuels. In Europe 4-6% of gas and oil is used for the production of plastics. This is a relatively low amount when compared to the 45% that transportation takes up (Plasticeurope, 2017). However, large amounts of plastics are incinerated. This amount is rising and is causing serious CO2 emissions (EC, 2016).

Next to CO2 emission and the usage of fossil fuels, plastic is also known for its litter problem and the formation of plastic soups in the oceans. It can take 100s of years for plastic to break down in the natural environment (thebalancesmb, 2018). Exposure to uv-light helps to break down the molecular chains in plastics. Plastics that end up in the ocean and are exposed to a lot of sunlight break down much faster (Harris, W. 2010). This results in tiny fragments called microplastics and are also found in animals and drinking water. Studies show that these microplastics can be dangerous, but the precise impact on human health is still not clear (Thamesproject, 2018).

Living without plastics is hard to imagine in the modern day society. It has greatly increased quality of life for the masses. Developing alternative materials, reducing unnecessary use and preventing pollution on land and water of plastics, are all necessary developments to minimize environmental impact. However, for a lot of applications plastic is still the best option in case of functionality. Unfortunately a closed recycling system is missing.

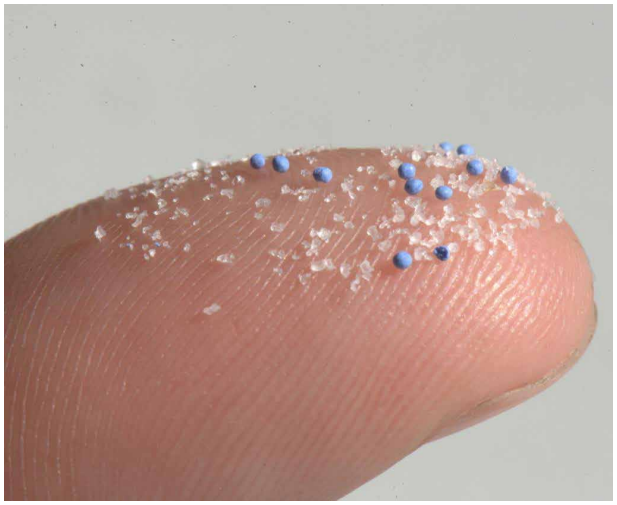


fig. 1.1 Microplastics can also be found as scrub balls in showering gel.

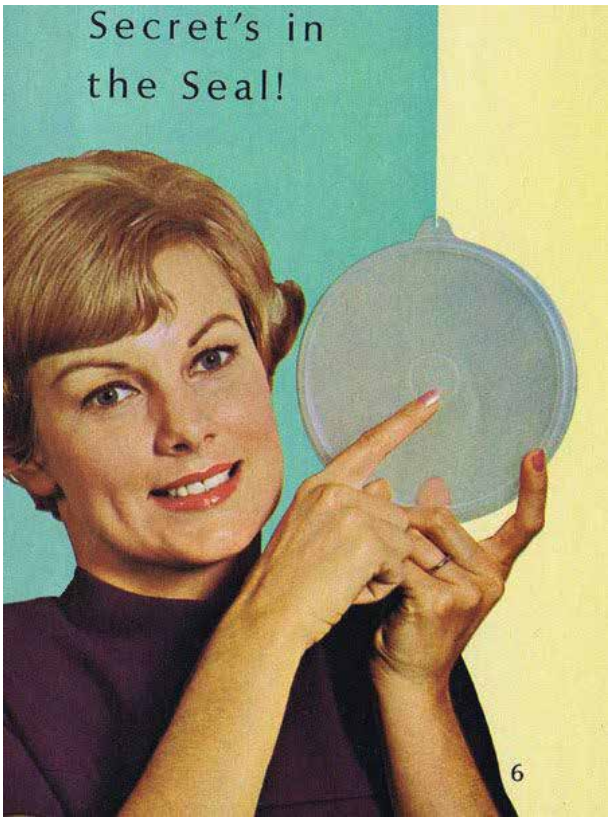


fig. 1.2 Tupperware advertisment pointing out the unique quality of the material

fig 1.3 Due to its light weight, plastic also helps to increase fuel effiency. Plastic makes up for 50 percent of a car's volume, by only contributing to 10% of its weight.

1.3 RECYCLING

Recycling is a way to improve upon the problems surrounding plastic in multiple ways. Plastics are used for a lot of applications, like packaging material, that have a short lifespan. Most of the economic value of this material is lost after a short first-use cycle (EllenMacArthurfoundation, 2016). Recycling aims for expanding the lifespan of a material. Estimates show that recycling all global plastic waste can potentially save an annual energy consumption equivalent to 3.5 billion barrels of oil per year (Rahimi, A. García, M, 2017).

At the moment less than 10% of plastics are being recycled, most plastics end up in landfills or the natural environment (Geyer et al. 2017, Leblanc, R. 2017). The demand for recycled plastics today accounts for only around 6% of plastics demand in Europe (EC, 2016). At the moment, the commonly known use for recycled plastic is that of low quality applications like roadside posts. Investments in recycling plants are often held back because of uncertainties in profitability.

At the moment recyclers are often competing with virgin producers, this is not an easy business for recyclers. Instead of competing it would be better if the would work with a closed recycling system. This means mixing recycled material with virgin to reduce the production of virgin materials (Rem, P., 2018). Other materials like glass, paper and metals do have these systems. Here it is the norm to mix recycled material with virgin to create new products. For PET bottles this is already an integrated system. This does mean that the recycled material should be close to virgin quality. Many different applications, types and grades do not make plastic an easy material to recycle. For metals this is not different, but the profitability of recycling these materials has lead to improved recycling methods for this. In order to implement recycled plastic, it should be seen as a worthy material that does not add too much pollution into the system.

The assignment for this project comes from the company Urban Mining Corp (Umincorp). Umincorp is a company that is aiming to make an economical viable business of recycling plastic by creating high purity monostreams.

fig. 1.4 Roadside posts made from recycled plastiss

fig 1.5 Biodegradable plastics are made from renewable resources and can be composted under the right conditions. Unfortunately, this way of composting is often not compatible with the current composting systems in waste management. Biodegradable plastics can also pollute the recycling steams of other plastics (RUG, 2018)

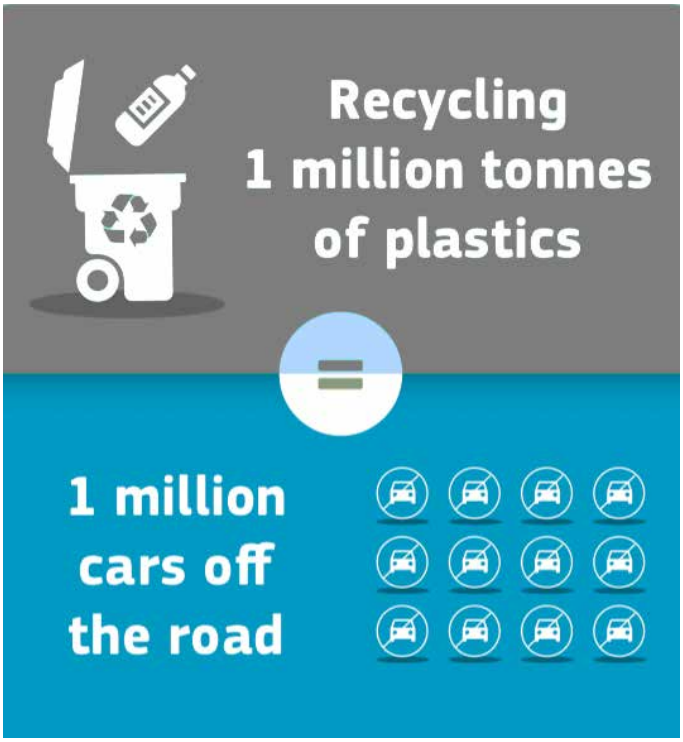


fig. 1.6 Impact example, (EC 2016).

''In the future the world will start to use less gasoline, but it will use more and more plastic. This is inconvenient, because with the process of cracking oil the fractions for both of these products are released in the same ratio. Less gasoline will mean les polyolefins. If you want more of these, you will need to recycle.'' (Kunststoffenenrubber, 2018)

1.3 URBAN MINING CORP

High prices and impurities in the output of common plastic recycling methods make it difficult to switch from virgin to recycled for producers and designers. Urban Mining Corp has developed a new technique to cope with these problems. Instead of using the conventional way of an object sorting system, they have found a way to separate plastics on their differences in density. This is made possible with their magnetic density separation system (MDS). It can be seen as an advanced sink-floating technology. A magnet influences a mixture of water and a ferromagnetic fluid to create multiple density ranges. Mixed materials are send through this mixture and are separated on density fractions. Laminar flows help to direct these fractions into separate batches. (A more extended explanation about this technique can be found in Appendix 2)

The accurate separation of mixed materials in a single step is a huge benefit of this technique.

''The modern city as an urban mine
Our cities are responsible for the vast majority of the world wide consumption of materials. Most of the materials we use on a daily basis can also be mined on a daily basis from the materials that we dispose of. Compared to conventional mining, this urban mine often has higher "ore" grades, is located close by and above ground. Its many benefits make it a mine worth mining!''

Processing costs are lower compared to current sorting technologies and the system is smaller. This smaller system makes it more accessible to apply in existing sorting facilities. A high throughput is possible and makes it suited for big waste streams like household waste. The recovery rate is high, this means less incineration and more high quality recycled output per ton of waste. Where current object sorting technologies are struggling to obtain a 95% purity (usually lower) from post consumer waste, Umincorp is able to deliver 99% purity. These benefits all contribute to offer cheaper recycled plastics with a higher quality.

fig. 1.7 MDS System in Biddinghuizen

fig. 1.8 Umincorp's unique selling points (Umincorp 2018)

At the moment Umincorp is building a fully operating recycling plant in Amsterdam right next door of the collector of household waste in that area. The recycling plant is designed to process post separation municipal waste. This means that source separation, the separation of waste by citizens, is not a necessary step. The amount of source separation in urban areas is relatively low compared to rural areas. Dense infrastructures and high-rises make it less accessible to separate waste and more expensive to collect (Dijkgraaf, E & Gradus, R, 2014). It also shows that post separation gives a higher output of plastic collection per citizen (Velzen van, T. et al., 2013). Depending on the area, urban or rural, it should be decided if source separation or post separation is more effective. (Dijkgraaf, E & Gradus, R, 2017). Building a recycling plant next to the collector of post separation waste is a cost efficient way to recycle. Moving waste to different plants and steps like creating waste bales will be unnecessary. The recycling chain should be kept short.

Keeping the chain short and the costs low is one part of the strategy of Umincorp, the other part consists of creating monostreams that are as pure as possible. These pure monostreams should help to make it more accesible to use recycled plastic for new products. Umincorp aims to deliver high purity colour separated monostreams. The technique for colour separation is still under development.

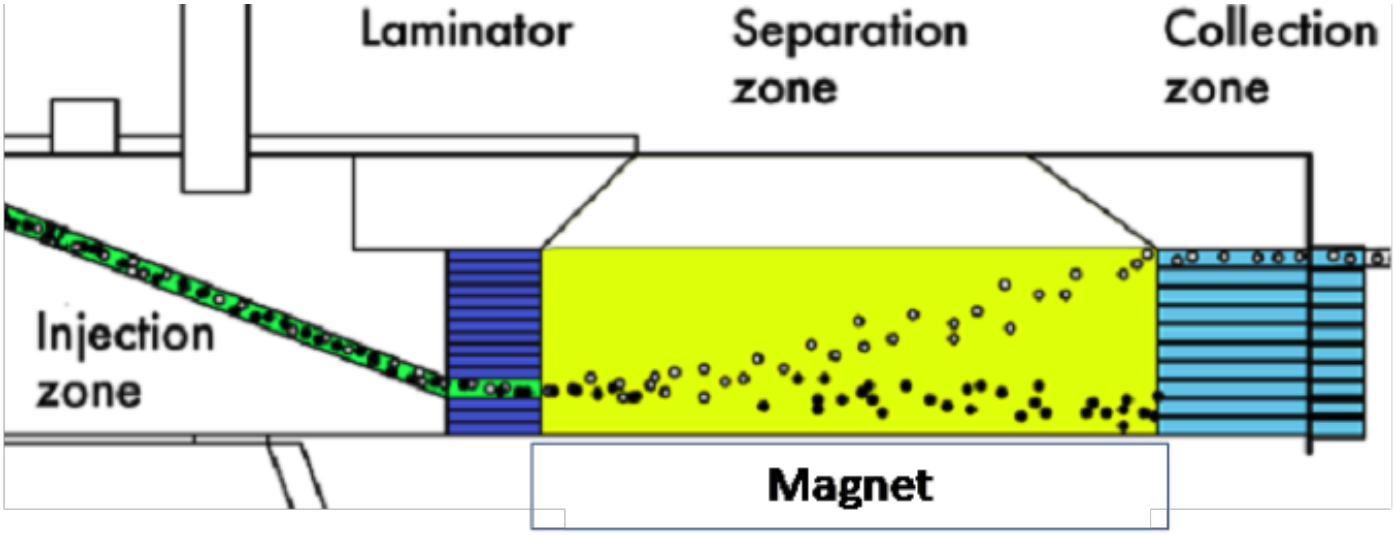


fig. 1.9 Simplified explenation of MDS (Umincorp, 2018)

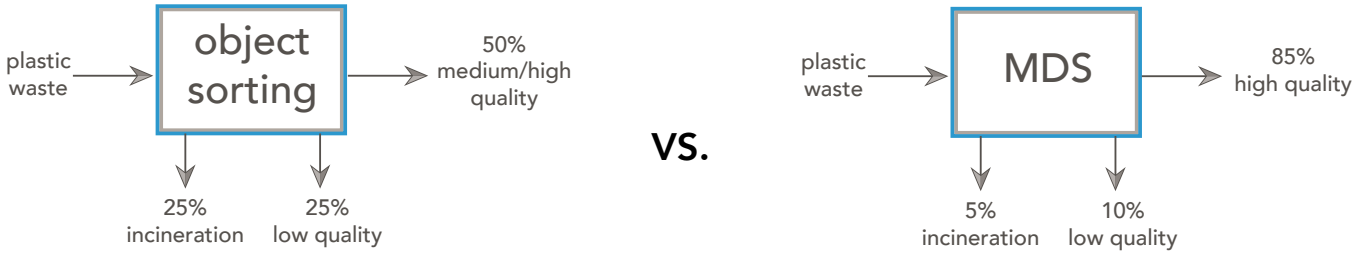


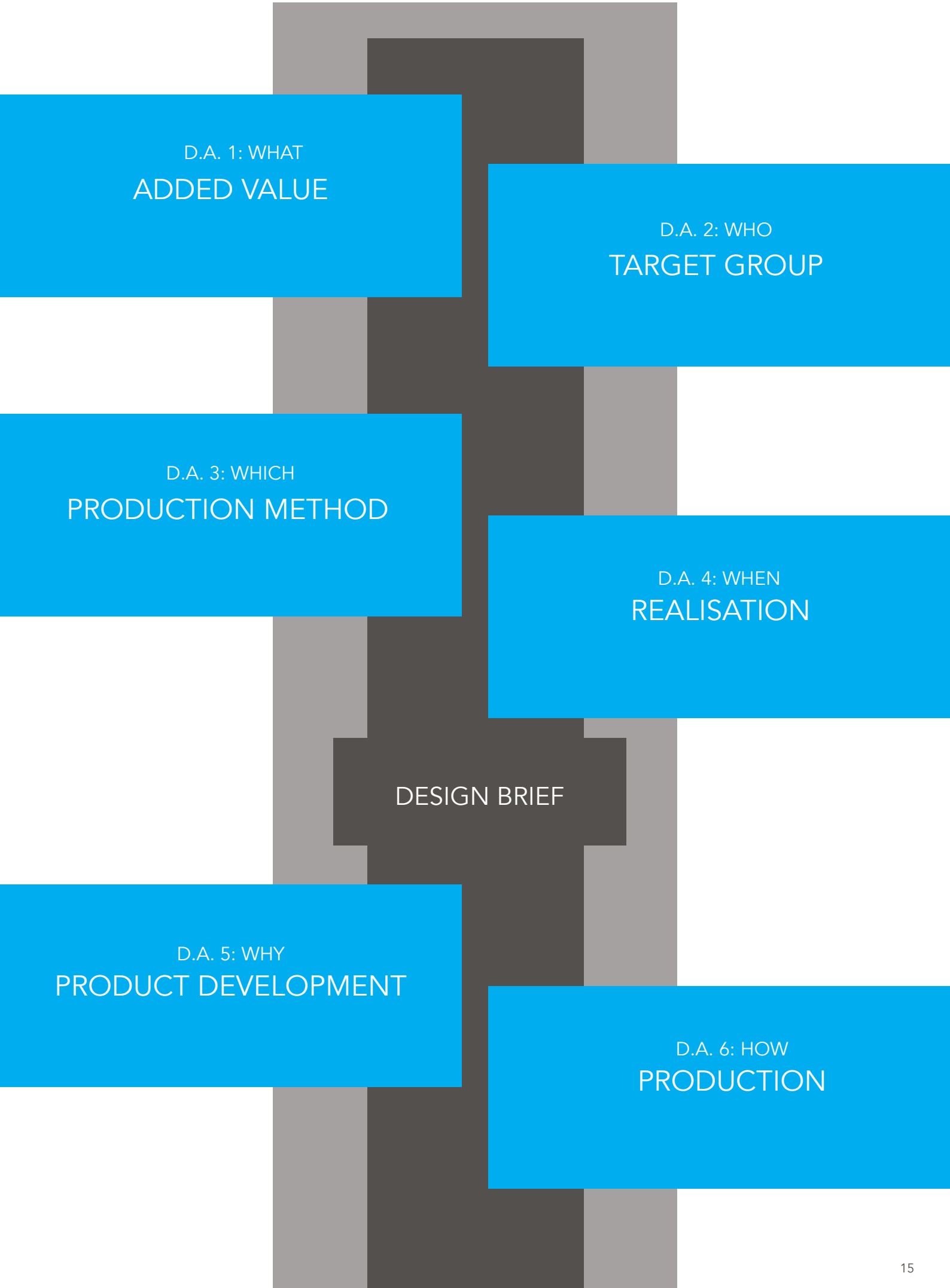
fig. 1.10 Object sorting compared to MDS

1.5 APPROACH

The following questions are composed to help gather information and narrow down the broad scope of the assignment.

- What value can Umincorp offer by developing a product for the intended user?
- Who of the relevant stakeholders will be targeted by this product?
- Which production method will be used?
- When can the product be realised?
- Why should the specific product be developed?
- How does Umincorp gain insight from the realisation of this product?

These main questions are translated into 6 decision areas as can been seen on the next page. Each decision area will consist of multiple related questions that will be introduced at the beginning of each chapter. When all the questions within a decision area are discussed, a conclusion for that area will be made. The first 4 areas will result in a design brief that acts as a more detailed version of the original assignment.


D.A. 1: WHAT
ADDED VALUE
D.A. 2: WHO
TARGET GROUP
D.A. 3: WHICH
PRODUCTION METHOD
D.A. 4: WHEN
REALISATION
DESIGN BRIEF
D.A. 5: WHY
PRODUCT DEVELOPMENT
D.A. 6: HOW
PRODUCTION

2.

ANALYSIS

This chapter is composed to find awnsers to the follow questions:

- What value can Umincorp offer by developing a product for the intended user?
- Who of the relevant stakeholders will be targeted by this product?
- Which production method will be used?
- When can the product be realised?

The outcome of this analysis results in a project brief that will be used for the further development of a product for Umincorp.

CONTENT

2.1 ADDED VALUE

In this chapter Umincorp's material is compared to the current market of recycled plastics. Characteristics of the material that are present due to the process of recycling will be explored to gain more understanding about the quality. Answers to the following questions will be looked for to gain an understanding of the market for recycled plastic and the value of Umincorp's material within this market.

- What type of material has Umincorp got available?
- What are the characteristics of Umincorp's material?
- What products are produced already?

- What issues arise when recycled plastic is used for mass production?
- What value can Umincorp offer by developing a product for the intended stakeholders?

2.1.1 UMINCORP'S MATERIAL

OUTPUT

Umincorp will focus on the separation of household waste, this will result in the output of plastics that are most commonly found in this type of waste stream. It is expected that the new facility in Amsterdam will have an output as can be seen in fig. 2.1. Another material stream Umincorp is processing consists of HDPE from bottle caps.

According to Umincorp they are able to sell their recycled flakes of 99% purity for around €950 per ton. The price of virgin material lies around €1500 depending on the oil prices and plastic type (see chapter 2.1.4).

A lot of the PET material that Umincorp encounters consists of multiple layers. These multi-layered materials are often found in food related packaging and can go up to 12 different layers (Polymerdatabase, 2015). To separate this an extra step of chemical separation is necessary. This technology still needs to develop further. For now the focus lies on finding applications for the PE and two HDPE material streams. Datasheets for the currently available material streams can be found in Appendix 3.

fig. 2.2 HDPE from bottlecaps (left) and PP (right) recycled by Umincorp

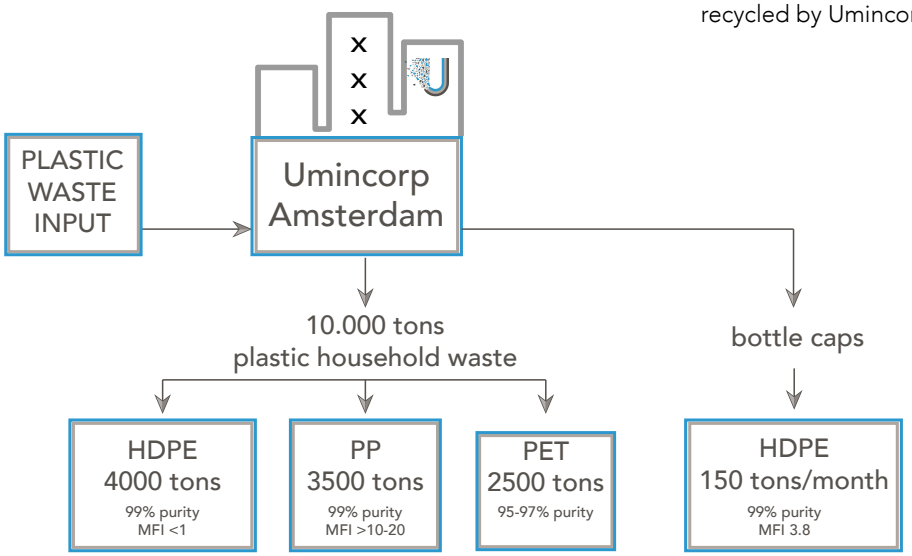


fig. 2.1 Expected output of the new facility in Amsterdam

CHARACTERISTICS

The high purity of Umincorp's materials means that there is almost no pollution of other materials. There are however other factors that influence the characteristics of the recycled materials.

Shortening of molecular chains

Thermoplastics like PP and PE are well suited for recycling, however the amount of times a thermoset plastic can be reshaped is limited. Each time the plastic is recycled the polymer chains get shorter. This is a result of the repeated heating, deforming and UV-degradation of the polymers. After about 7-10 times the quality of the plastic will start to decline (Plasticstoday, 2018) .This lowers the molecular weight and causes deterioration of mechanical properties (Yousif E, Haddad R., 2013).

For PET this is less of a problem than for example PP or PE. Differences in polymerisation reactions make it possible for PET to attach chains to each other to restore chain lengths. This is not possible for PP or PE (Appendix 4 interview M. Faber)

Differences in MFI

An important specification for processing polymers is the melt flow index or MFI. The MFI describes the ease of flow of the material. It is defined as the amount of weight in grams flowing through an extrusion head in ten minutes with a certain pressure and temperature applied to the material (see fig. 2.3).

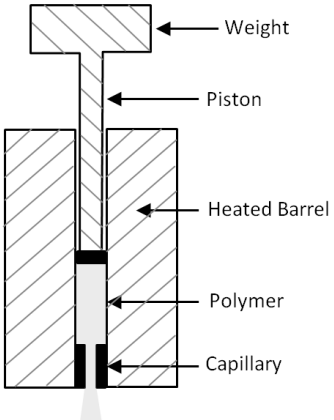


fig. 2.3 MFI measurement (Impact-solutions, 2017)

A high MFI indicates that the material has a low viscosity. The MFI can be different for the same type of plastic. When there are two types of PP, one with a MFI of 1 and the other with a MFI of 15, it means that the PP with MFI 1 has the highest molecular weight (Polymerdatabase, 2015). So in general, a relatively high MFI means lower material strength.

When forming a material into a product, compromises should be made between a material that has the right amount of flow and also enough strength. The mix of different MFIs in recycled material streams makes it difficult to create a constant MFI for separate batches. This can be problematic when buyers rely on the availaibilty of a constant MFI.

Differences between HDPE and PP that is found in household waste are:

- PP within household waste mostly comes from injection moulded products with a relatively high MFI.
- HDPE within household waste mostly comes from blow moulded products with a relatively low MFI.

Blow moulding and injection moulding will be the most obvious production methods to look into when looking at the MFI and origin of the material.

Mixed additives

Mixing the polymers with additives can modify MFI, colour, flexibility and many other properties. These additives are the ingredients that make it possible to create such a wide variety of a single type of plastic. In for example the PP stream of Umincorp there are different types of PP that all consist of a wide variety of additives. There are certified standards for additives, however within the same groups there are still many variations from different producers (AccuStandard, 2013). Fig. 2.4 gives an idea of the different types of possible additves.

The mix of additives makes it difficult to establish

specific property outcomes in the recycled streams of Umincorp. There also exist organic and mineral additives that cause problems when melted together for recycling (Kunststoffenrubber, 2018). Technology to scan material streams with mixed additives is not yet implemented on a large scale, however it is being developed to cope with these problems (Polytential, 2018).

Antioxidants	Protect polymer against oxidation
Fillers	Can change physical properties or reduce costs
Flame retardants	Reduce or prevent combustion
Heat stabilizers	Prevent theremal degradation
Light stabilizers	Reduce reations causued by visible or UV-Light
Odour modifiers	Mask an undersirble odour or add a desirble one
Plasticizers	Enhance flexibility
Smoke suppressants	Reduce smoke formation when combusting
UV-stabilizers	Preserve from UV-radiation

fig. 2.4 Examples of different additives

2.1.2 PLASTIC MARKET

Fig. 2.5 gives an overview of different markets in Europe and the types of plastic they use. Within the Netherlands over 1300 companies are taking part in the plastic processing industry. The plastic sheet and profile industry, plastic packaging and plastic construction products are the biggest groups within the whole cluster (Dutchform, 2018).

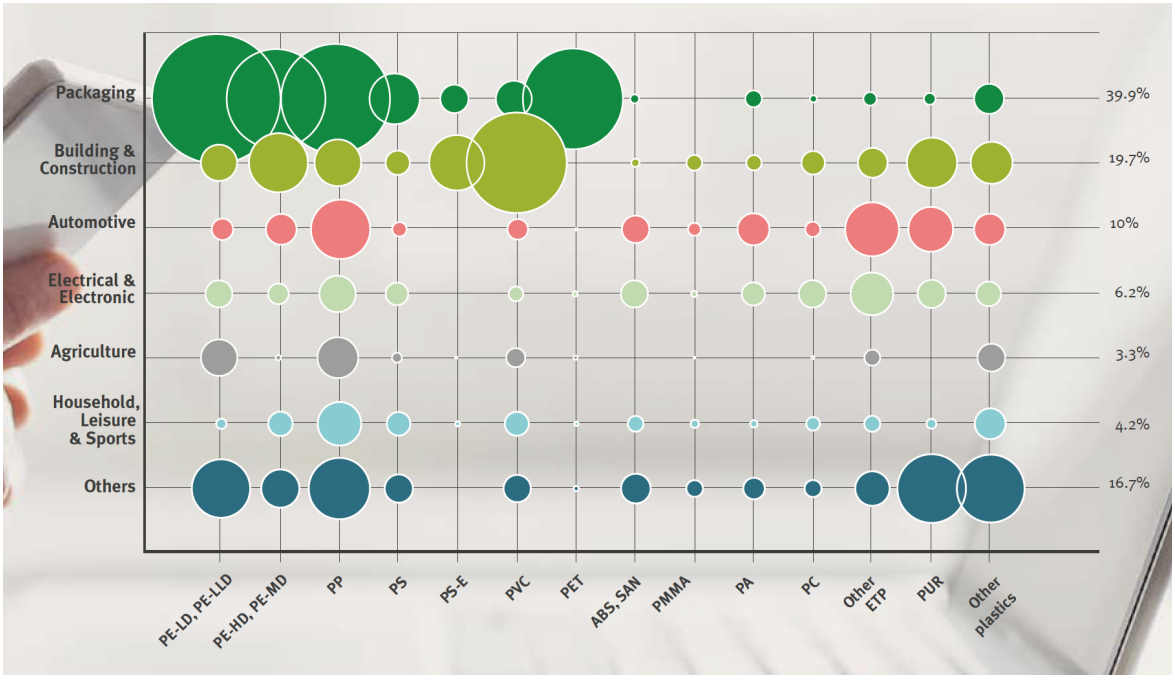


fig. 2.5 Plastic demand by segments and polymer types (Plastic Europe, 2017).

''Looking beyond the current take-make-dispose extractive industrial model, a circular economy aims to redefine growth, focusing on positive society-wide benefits. It entails gradually decoupling economic activity from the consumption of finite resources, and designing waste out of the system. Underpinned by a transition to renewable energy sources, the circular model builds economic, natural, and social capital.''
(Ellen Macarthur Foundation)

POSITIVE DEVELOPMENTS

Umincorp's material comes with certain complications. There are however also positive developments that will help create a demand for this material. A trend analysis was conducted to look into positive developments that are relevant for Umincorp. The findings are summarised above into seven statements. The full analysis can be found in Appendix 5.

- The increasing amount of waste asks for more or improved ways of processing it.
- The increasing urbanization asks for more waste processing in relatively small areas.
- Funding from governments and companies is helping the recycling sector to development further.
- Increasing governmental intervention can create a push for incorperating recycled plastics into products.
- Recycling will stay an important part of a circular economy
- Rising awareness among citizens can increase the demand for recycled plastics
- There is a demand for higher quality recycled plastics

ENTERING GUIDELINES

The following guidelines are set up to help define which type of products can be a suitable and accessible starting point for development with Umincorp's material.

Specific material properties HDPE and PP

The properties of the material should be suited for the type of product it will be used for.

High production/material volumes

Umincorp will be processing high volumes of plastic waste. Finding a production method that can process these volumes or a product that has a high material volume will be a suitable direction to manage the output.

Lower technical requirements

Recycled plastics could result in lower technical qualities due to the shortening of molecular chains and the presence of impurities. Finding an application that does not ask for high technical requirements can make the use of recycled plastics more accessible.

Reusing for a similar purpose

Putting the recycled material to use for the same application it was used before would be a logical option. Specifications and additives present in the recycled material would be relatively similar to what is needed for the new product.

Local market

Finding opportunities for re-use closer to the material source will save transportation costs and emissions. Production markets in or close to the Netherlands would be the preferred options.

Consumer product

Trends in sustainability and social pressure can help to create an increasing demand for products made from recycled plastics.

2.1.3 EXISTING PRODUCTS

Some examples of products produced from post consumer monostreams are shown here. This gives an image of what kind of products other companies are producing and which design considerations where taken into account. In order to get to a feasible end product for this assignment, similar considerations have to be taken into account. These will be listed in the design brief of chapter 2.5.

fig 2.6 Elho watering can from 60% recycled post consumer waste.
Limitations:1,3,6 (Elho, 2017)

fig 2.7 Collection vessel for hospitals. In cooperation with Suez and QCP.

DESIGN CONSIDERATIONS

1. Only part of the plastic used is from recycled material
2. The monostreams where obtained from pre-sorted waste
3. The design of the product starts off over-dimensioned
4. Mixing with some percentages of virgin material
5. Small or single production batch
6. Extra optimization of the mould through trial and error

fig.2.8 SEEPJE bottle from 97% recycled post consumer waste.
In cooperation with QCP.
Limitations: 1,4

fig. 2.9 Greentom strowler from 100% recycled household waste. In cooperation with QCP.
Limitations: 3

fig. 2.10 Circular Clockworks watch in cooperation with Coolrec.
Limitations: 5

fig. 2.11 Office chairs and desk in cooperation with Vepa, Plastic whale and Umincorp
Limitations: 5

fig. 2.12 The New Raw 3D printed bench in cooperation with Umincorp

fig 2.13 Philips vacuumcleaner with 1.5 KG recycled pp. In cooperation with Veolia.
Limitations: 1

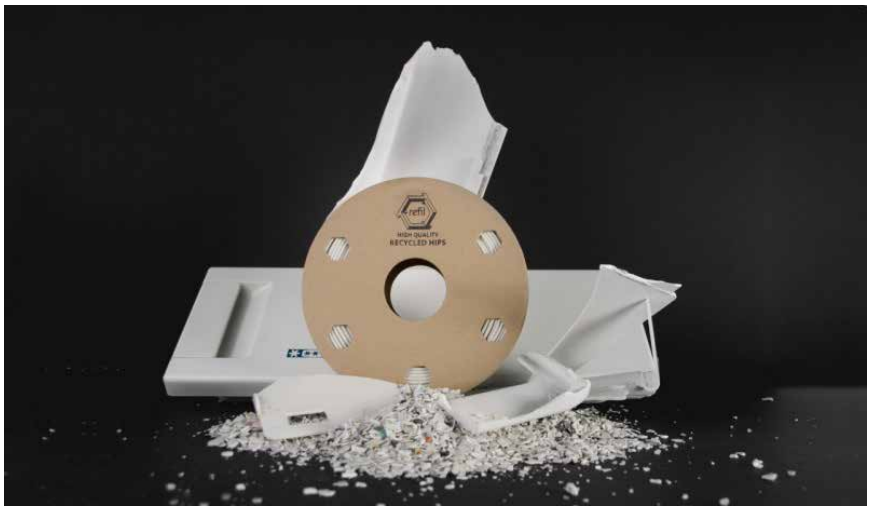


fig. 2.14 Refill 3d printer filament made from old refrigirators. In cooperation with Coolrec.
Limitations: 5

2.1.4 BOTTLENECKS

This chapter elaborates on the different factors that influence the decision to use recycled plastics. These findings will be used to conclude what value Umincorp's material has to offer in the current situation.

RESEARCH QUESTIONS AND INTERVIEWEES
Experts from the industry where contacted to gain more understanding of what is holding back the plastic processing industry to use recycled plastics. The following research questions where composed:

Why is recycled plastic not being used already?

How do producers perceive recycled plastic?

What are important factors that influence material choices for production of plastic products?

A wide range of experts within the plastic processing industry was contacted throughout; face to face interviews, phone calls, company visits and attendance of public events like the Kunststoffenbeurs or Blue City. Material samples where given out and tested with or by; Mafa injection moulding, Zweva Rotomoulding, Plastirol foil extrusion and Precious Plastic. The findings from the interviews are combined with desk reserach and summarised in this chapter. The results of material tests can be found in chapter 2.3.1.

Material price

The material price is an important factor when switching to a different material. A common demand to switch from virgin to recycled material is to get it for a lower price. Changing to recycled material can ask for investments in production time, product modification and uncertainties about quality control. Using recycled plastic instead of virgin often ends up in similar or even higher material costs (Researchandmarkets, 2018). Low oil prices and established techniques to create virgin plastics make this a difficult competitor for recycled plastics.

FIGURE gives an overview of the prices of virgin and recycled commodity plastics in 2018. The recycled overview also shows the difference in price between regrind (or flakes) and re-granulated plastics.

''It will start getting interesting when the material costs will be significantly lower''
(Zweva rotomoulding)

Making granules from the regrind can easily add €200 per ton of material, a costly step in the recycling process. Producers of for example the packaging industry will notice an even bigger price difference. Disposal fees of plastic packaging in the Netherlands can add up to €640 per ton (Afvalfondsverpakkingen, 2019). This can motivate producers to look at other material options then virgin. Developments in: regulations, recycling techniques and higher oil prices all help to make recycled plastic a stronger price competitor.

A summarize of the interviews with the approached contacts can be found in Appendix 4.

APPROACHED CONTACTS

Seepje
GreenTom
Plastirol
(producer foil exstrusion
Zweva
(producer, rotomoulding)

Euromoldings
(producer, blow moulding)
Mafa, P3d
(producers, injection moulding)
3d Printing expert
Kunststofprofielen
(producer, extruder of profiles

Polymer expert
Extrusion artist
Precious plastic
Packaging designer
Better future factory
Kunststoffenbeurs
Blue city

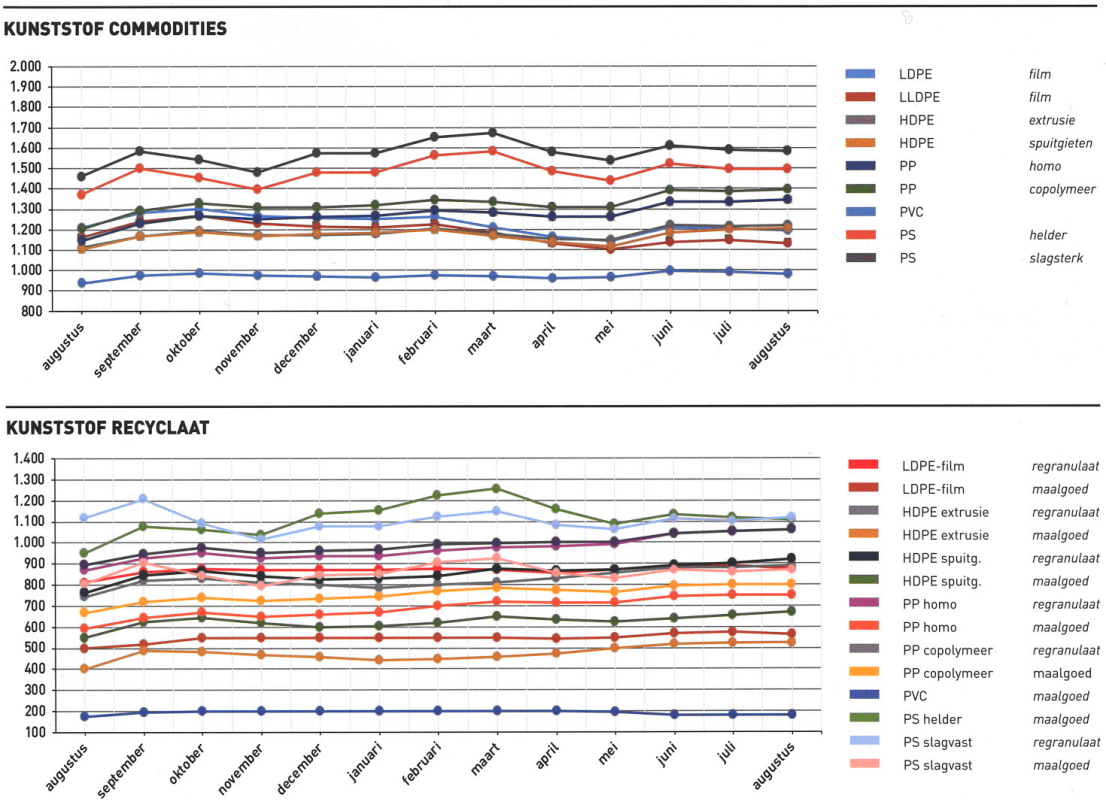


fig. 2.15 European prices (€ y-axis) in 2018 per ton of commoditie plastics vs. recyclet plastics. Source: Kunststoffenmagazine, 2018

Regulations

''The EFSA, or European Food Safety Authority, has issued upward of 140 positive scientific opinions on the safety of processes to recycle plastics for use in food contact materials. The European Commission could therefore officially authorize the evaluated processes. To date, however, it has displayed no initiative in that direction. The absence of EU legal framework prolongs the lack of harmonisation amongst Member States and generates legal uncertainty and unnecessary burden for the industry using recycled materials.'' (Plasticnewseurope, 2017)

Within the Netherlands there are norms that control the quality of recycled plastic to a certain extend. Municipalities receive an annual compensation when recycled material meet these so called DKR standards. (Nedvang, 2015) These standards are not directly linked to for example the EFSA or medical applications. For these kinds of applications it must be proven that the material does not contain any toxic or harmful components (WUR, 2017).Traceability of the plastics origin and usage is a challenge for the mix of products that end up in household waste.

There are possibilities to use recycled plastic for food packaging. This asks for the use of 95% recycled food grade material. In practise this means that the material should have been used as food packaging before (Kort et al., 2018). In the current system non-food and food-packaging are not collected separately.

Purity and perception of quality

A higher purity recycled material is preferred because of; processability, quality control and perception of quality.

''Technical products needs to have a perfect surface quality, this gives a feeling of quality for the customer'' (Mafa injection moulding)

When materials with different melting points are mixed together, it can result in imperfections in the end product. A higher purity material will result in less imperfections in the end product. For production methods like blow moulding, small impurities can already cause problems because of leaks that are occurring during the production process. When producing bottles, this is not something that is acceptable.

The purity of recycled monostreams should be high in order to be accepted into a closed recycling system. This is a better starting point for the compounding of new granules. Furthermore, high purity can also help to improve the image of the inferior quality of recycled material.

''We do not sell recycled materials because we want our costumers to view us as a distributor with only the highest quality materials''
(Prime Polymers, sales representative)

Colour

A known image of recycled plastic is that you eventually only get grey and black products from it, due to the mixing of different colours. For producers this can be a problem, because customers will demand different colours for a lot of products.

''Al lot of our PP and HDPE products are requested in colour, this makes it difficult to switch to using recycled material'' (Mafa Injection moulding)

Some companies show that there are opportunities with colour when it comes to using recycled plastic from household waste. For example, Greentom (Greentom, 2018) designed a white stroller made from 100% recycled household waste. Creating this white plastic is made possible by the compounder that they work together with (QCP). The company Seepje sells a green and blue soap bottle made from 97% recycled household waste (Seepje, 2018). By adding a few per cent virgin material, coloured products can also be made possible.

Mixing with virgin material, colour sorting or applying the expertise of compounders can make it possible to create coloured products from recycled plastics, if clients are willing to invest in their material price.

fig. 2.16 Granules from recycled plastic without added pigment and with black pigments added to them.

fig. 2.17 Coloured bottles from Seepje produced with recycled household plastic waste from QCP.

Availability of constant specifications

A problem with recycled material from household waste is the differences in specifications between batches. These differences exist due to the changing input of the waste material. Virgin materials are able to offer steady material specs between different batches.

With the start of the production for a new product, material tests are performed by producers to find out if the chosen material meets the requirements in practise. Producers like to have access to a steady available material stream when buying a new batch. If the material stays the same for the following orders, no extra material tests need to be made. When the specifications of material streams differ between orders it means they have to do test runs between these deliveries. This results in higher start-up costs and lower production output.

High volume productions ask for reliable material qualities. Not every product can be checked for imperfections. Employees are often running multiple machines at the same time. When for example an injection moulding machine is using recycled plastics and is producing products with imperfections, it can ask to have the settings adjusted. This can ask for near constant attention of a production employee, something that is not calculated in most production processes.

''We are used to a 'Plug and Play way of working. Fine tune the production for the first batch of material and keep production going throughout different batches ''
(Promolding, injection moulding)

Transparency of specification sheets

Producers work with specification sheets of the material they buy. This information gives insight in the ability to process the material and the specifications to meet the product its technical requirements. These sheets are made available by producers and can also often be found in material databases like; CES Edupack or Universal selector. Specifications sheets of recycled materials should be available just like that of virgin materials. Making these sheets more transparent by adding them to material databases increases the accessibility. More producers and also designers will find these sheets and can consider recycled plastic as an option for their material choice. QCP, an established player in the market of recycled polymers, sets an example by making a wide variety of datasheets available on their website (Lyondellbasell, 2018).

MFI and compounding

Some production processes like injection moulding use a high MFI where other processes like blow moulding use a much lower one. Not all MFIs are suitable for every production method. MFI gives an understandable specification for producers about a certain plastic without having to go into specifics like molecular composition. Producers can for example tweak their production process by trying out materials with different MFIs and choose their optimal solution.

It can cause problems when materials with different MFIs and different additives get compounded to make new granules (Kunststofenrubber, 2018). When recycled material streams are constantly changing in MFI it becomes difficult for compounders to make new material. If the recycled streams are more or less constant in MFI it will be much easier to blend with other sources to create the desired compound (Impact solutions, 2017).

Using recycled flakes directly without turning them into granules first is not a way to obtain a constant output. Specifications are not homogenous divided throughout one big bag of recycled flakes.. Besides this, most fines (smallest pieces) will eventually end up at the bottom of the big bag, thus creating an uneven distribution of material. To help overcome these problems, a quality compound should be made where the mix of additives and impurities in the recycled material is mixed into a more homogenous material.

Odour

Recycled plastic has a tendency to smell, it does in the end come from consumer waste. This is something that can be minimized by washing the material or by adding additives that modify odour. The material available for this project is characterised by a strong 'soapy' smell.

Circular product design

A circular economy asks for designing circular products that are easier to recycle. Reuse, repair, redistribution, remanufacture and refurbishment of products should also be a part of this (EEA, 2017). The idea of designing the end of life into a product is not something that has always been used by every designer. Although there are regulations about material use (like disposal fees), circular product design is not mandatory by law. Circular product design is less focused on maximising economic growth. This can make it less interesting for companies that are trying to compete in a capitalistic environment. Recycled materials will benefit from trends in sustainability and companies that do adopt a more idealistic mind-set.

''Designers should be educated to incorporate circular product design as a standard requirement. At Greentom we show that this way of product design is realistic, it just asks for an adjustment in approach and mind-set.'' (Designer at Greentom)

The bottlenecks found in this chapter that influence the utilization of recycled plastic for mass production can be summarised as follows:

- Material price
- Regulations
- Purity
- Perception of quality
- Colour choice
- Availability of constant specifications
- Transparency of specification sheets
- Ability to make a quality compound
- Odour
- Circular product design
- Shortening of molecular chains
- Multi layered materials
- Mixing of Additives
- Availability of a suitable MFI

fig. 2.18 Umincorp's MDS in Biddinghuizen

Characterisitcs of Umincorp's material obtained by MDS technology that are analysed so far are:

Strenghts:
- Delivering a high purity monostream.
- The material is price competitive.
- Processing of large amounts of waste.
- High recovery rate of the material.
- The relatively small system makes it accessible to apply in more facilities.

Weaknesses:
- Limited colour range
- Specification differences per batch
- Food grade not yet available
- Mix of additives
- Multilayered materials are still an issue for recycling

Opportunities:
Growing amount of funding will help to improve the recycling system.
Growing amount of waste asks for more ways to process it.
Possibility of recycled material becoming an obligation by governmental regulations.
Growing awareness of citizens can increase the demand for recycled plastics.
Direct use of the flakes without compounding will lower the material price.

Threats:
Negative aspects of plastic take over the consumers view
Decline of material after multiple recycling cycles

Conclusion D.A. 1: ADDED VALUE

High purity monostreams for an economical viable price is the main value that Umincorp can offer with their MDS technology. By developing a product from their own material they will be able to show a result of what their high purity material can achieve.

Besides this the product can also set an example of how other bottlenecks for utilizing recycled plastic can be overcome. A decision will be made between which bottlenecks will be included that are relevant for the intented target group and also achievable within the project. The bottlenecks that are defined as less suited for showing the material its value during this project are:

Regulations
MDS is not designed to create food or medical grade recycled plastic. Other technologies like chemical separation and focussing on refining governmental regulations could improve this in the future.

Availability of constant specs
Creating reliable, Wnon-deviating material streams and a range of specifications to optimize production time is something Umincorp should aim for. This will depend on a steady input of material, further development of their recycling system and cooperation with external parties. Mixing the recycled material with a small percentage of virgin could also be a necesarry step to achieve this.

Ability to make a quality compound
To save time and money, a compounding step to create new granules from the flakes will not be included within this project. CHAPTER will look into the possibilities of adding the flakes directly to a production process.

Improvements on; the shortening of molecular chains, mixed additives, multi layered materials and odour rely mainly on optimised recycling techniques and compounding. The development of the product will be dependent on the current material characteristics, so it should be taken into account that this can influence the design, function and production.

Bottlenecks that are suitable to be linked to relevant product qualities are:

- Price
- Purity
- Perception of quality
- Colour choice
- Transparency of spec sheets
- Circular product design

These findings will be translated into design challenges that can be found in the design brief of CHAPTER.

2.2 TARGET GROUP

- What relevant stakeholders influence the demand for recycled plastic?
- Who of the relevant stakeholders will be targeted?

2.2.1 STAKEHOLDERS

Umincorp wants to increase the demand of their material. The product that will be developed during this project should support this. This chapter explores who influence the demand for recycled plastic and which stakeholder should be targeted as a suitable starting point for the development of the product. Fig. 2.19 gives an overview of the involved stakeholders that can be distinguished (according to: Kort et al., 2018) in the plastic; production, processing and recycling industry.

VIRGIN PLASTIC PRODUCERS

Virgin plastic producers add new materials to the plastic processing industry. They sell the material to producers that will process it into new products. Compounders are also part of this group; they provide additives that give specific qualities to plastics. Compounders can be a part of the company that produces the plastics, but they can also work as a separate company specialized in production of additives. Recyclers that sell recycled material can be

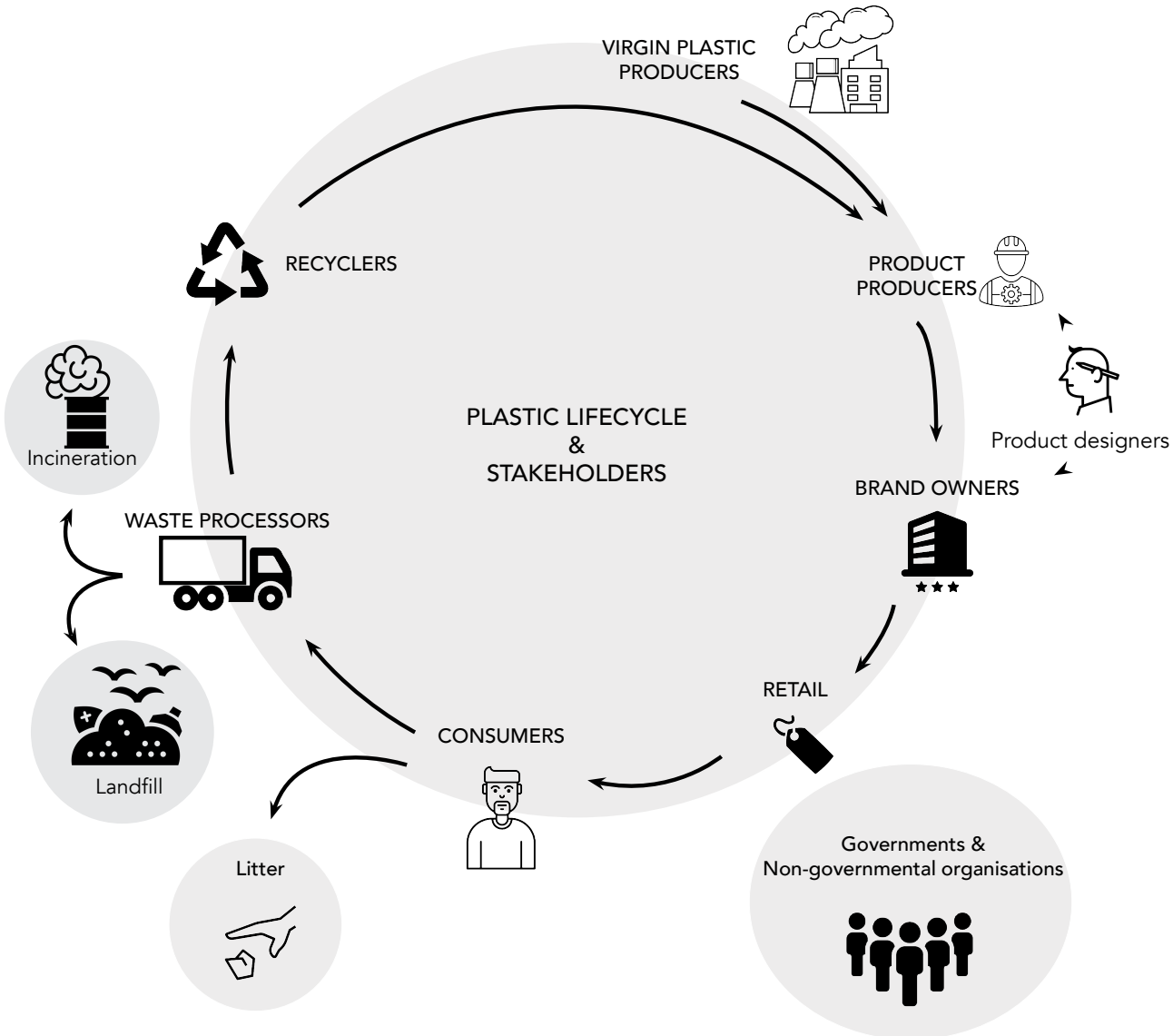


fig. 2.19 Overview of stakeholders in the plastic; production, processing and recycling industry.

competitors of virgin producers. The recent fusion of Lyonellbasell, a large producer of virgin plastic, and QCP shows that virgin producers and recyclers can also work together to incorporate recycled material into their system (Lyondellbasell, 2017).

PRODUCT PRODUCERS

A wide range of companies that produces products for different markets is part of this group. Large producers in the Netherlands are for example; Oelemans (foils), Promolding (injection moulding), Euromoldings (blow moulding) and Essentra (extrusion). Producers can choose to use recycled material where this is possible or when the customer demands it. Producers work together with product designers in order to realize the production. The designers can work for the producer or they can be a customer and work for a brand owner.

BRAND OWNERS

Brand owners are responsible for the design and specifications of a product. They can choose to use recycled material for the product they are developing. Material decisions by brand owners can be influenced by consumer demand and also regulations. Brand owners of, for example packaging products, are by law responsible for the collection and recycling of their products (Overheid, 2016). In practice they pay a disposal fee to partially transfer these responsibilities to another party (Afvalfondsverpakkingen, 2019). A large brand owner within this industry is for example Unilever or Philips.

RETAIL

Retailers trade and sell products as wholesalers or in stores to consumers. They can demand certain requirements from brand owners or product producers. Retailers can also function as brand owners because they often also sell own brands in their stores, for example Hema or supermarket chains like Albert Heijn or Jumbo.

WASE PROCESSORS

Source separation and post separation in the Netherlands is handled by waste processors like; Suez, Attero, Omrin, Midwaste or VanWerven. They collect and separate the waste while working together with municipalities.

RECYCLERS

Recycled material from waste processors is delivered to recycling companies like Veolia or QCP. They process the waste into recycled granules that can be sold and used for the production of new products. Some recycling companies, like CABKA or Lankhorst also make and sell their own products from recycled material. Umincorp is a recycler that delivers high purity recycled flakes instead of granules. Buyers of Umincorp its material need to use it directly for their production process or use it to make new high quality recycled granules.

GOVERNMENTS, NGO'S AND CONSUMERS

These stakeholders can also influence the demand for recycled plastics. Governments can introduce regulations that ask for the increase of utilizing recycled materials. Non-governmental organisations like The Ellen Macarthur Foundation or Plastic Soup Foundation help to create awareness for this topic. This also influences consumers and they can in return create a bigger demand for more sustainable products.

ANALYSIS

It is difficult to focus on a single stakeholder when trying to influence the demand for recycled plastic, because each individual stakeholder has limited influence and is dependent on other stakeholders. The amount of influence is dependent on the relationship between supplier and buyer and purchasing power of these stakeholders (Kort et al., 2018). Different approaches can be chosen to try and influence the demand for recycled plastic by designing a product.

Increasing awareness among citizens about sustainability and the importance of recycling is a way to create a larger demand from consumers. This is a topic that is already receiving a lot of attention within the current media. But so far it does not have a big effect on the use of recycled plastic (EC, 2016).

A change in governmental regulations could have a big impact on the use of recycled plastics when this for example becomes obligatory. Focusing on political issues lies however far from the scope of the assignment.

As stated in chapter 1.3, virgin producers can play a crucial role when working towards a closed recycling system where virgin material is mixed with recycled material. At the moment virgin producers are seen as recycler's main competitors, which makes this a difficult starting point for the assignment.

The recent investment in Umincorp by Ingka group (IKEA) (Afvalonline, 2018) is an example of a brand owner taking steps to accomplish their sustainable development goals. The impact of this will eventually depend on the possibility to utilize Umincorp's material. This is where the producers and designers come in. They are responsible for realizing quality, trustworthy products for their costumers. They need confidence that the material they use can guarantee this. Judging the value of Umincorp's material is something this group should be able to do.

Conclusion D.A. 2 TARGET GROUP

An entrance to influence the demand for Umincorp's material can be found by developing a product that focuses on convincing the designers and producers for those kinds of product. A lack of quality has been a limitation for the utilization of recycled plastics. Umincorp wants to show that their material can overcome these limitations. Producers and product designers should gain trust in the technical possibilities and quality Umincorp's material has to offer. From here out the demand of the material can increase when it becomes clear that it can be used as a reliable resource.

TARGET GROUP: Producers and product designers.

2.2.2 PRODUCT CONTEXT

- How will the target group be approached?
- How can the target group be characterised?

The context where the product will function in is further defined in this chapter. This is explored throughout; a visit to the Kunststoffenbeurs 2018 in Veldhoven, a creative session organised by two IDE students during the course Creative Facillitation (Appendix 6), a persona and a lifestyle collage.

The decision was made to develop a product in the context of a business fair. A business fair can be a great platform to reach out to experts and a network of businesses in the plastic processing industry. Next to the producers of the specific production method other stakeholders also come together on these fairs. Umincorp was present on the previous Plastic Recycling Show (PRS) and will be again 10 and 11 of april 2019. Other interesting fairs that are not mainly focused on recycling are for example: de Kunststoffenbeurs in Veldhoven, K-tradefair Dusseldorf and Maakindustry in Groningen. These fairs could also be interesting places for presenting the product.

fig. 2.20 Umincorp stand at PRS 2018

Kunststoffen 2018

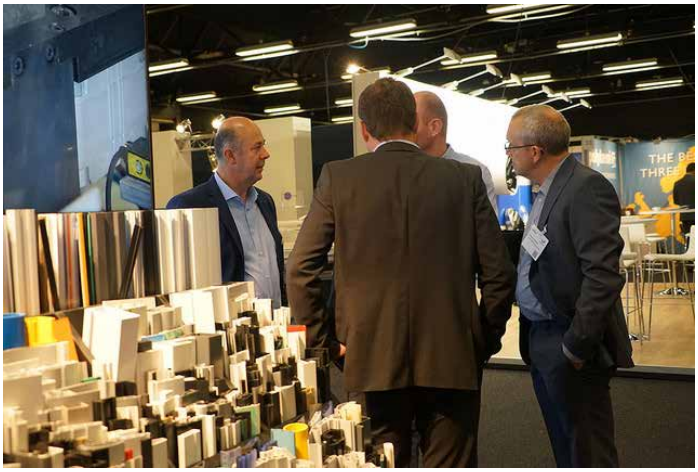


fig.2.21 Photos from Kunststoffenbeurs 2018 (source: Kunststoffenbeurs, 2018)

Bio

Arjan Smelting has a long history of developing injection moulded products. Part of his job is to work together with clients to find optimisations for their product designs. The company he works for can be seen as a mid-size producer. They are looking for opportunities to expand their market. Recycled plastics have been an interest of the company, but so far no great results where achieved.

'' I am looking for opportunities to optimise our manufacturing process and expand our business''

Name: ir. A. Smelting
Age: 40
Company: Inject Moulding
Function: R&D project manager
Experience: 15 years

Personality

- Curious
- Pragmatic
- Sceptical
- Sober
- Organized

Media

- Business events
- Business cards
- Email
- Mobile phone
- Linkedin
- Company phone

Goals

- Gather information about technology, material specifications, price, and availability
- Look for practical examples of applications
- Gain confidence for the feasibility of applications
- Find inspiration for the company's own projects

Motivation

- Growth of the company Inject Moulding
- Find useful business relationships
- Stay up to date with current developments
- Being able to adapt to the business environment

Accessories

- Smart phone
- Pens
- Business cards
- Wallet
- Nametag
- Free totebag including; flyers, give aways...

Previous experience with recycled plastics

- The company experimented with the application of recycled plastics before.
- Mostly applications for lower quality products were found due to impurities.
- High investments in time and costs for creating the right compound and fine-tuning of mould and machine settings.
- Follow up batch of material has different specifications; investment process needs to be redone.
- Clients are sometimes interested, but drop the idea when they learn about the complications.

Expectations about Umincorp's material

- High purity recycled material must be expensive
- There is still a noticeable amount of visible impurities
- Only grey or black products are possible
- Lower mechanical properties

Frustrations with recycled plastics

- Unreliable availability of constant specs
- More dropout products due to quality imperfections
- Limitation in colour
- More adjustments of production settings
- Un-interesting when trying to save material costs
- Spec sheets are more difficult to find
- Restrictions for some applications due to regulations

fig. 2.22 Persona, visitor Kunststoffenbeurs. Composed throughout interviews with the target group and a vsiti to de Kunststoffenbeurs

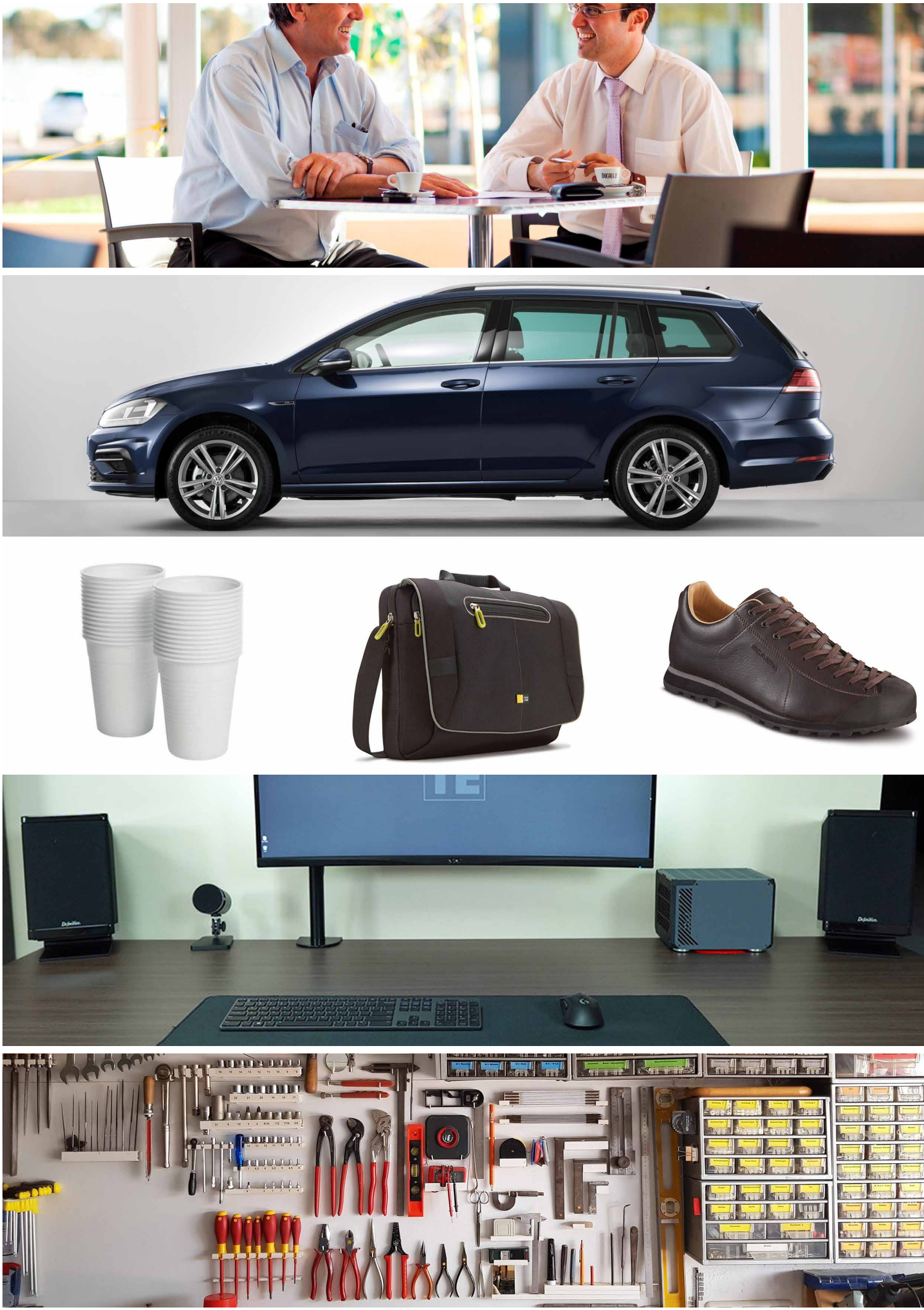


fig 2.23 Lifestyle collage visitor Kunststoffenbeurs

The product that will be developed should be appropriate to present on a business fair like the Kunststoffenbeurs. This is a business environment where companies present themselves to expand their network. Technical developments and business opportunities are emphasised here. Fig. 2.22 describes the persona of a visitor that is assumed as someone who is likely to interact with the product. A pragmatic and sober person that is not easily impressed will be an interesting and challenging starting point for the development of a product. The product should appeal to the characteristics of this type of persona within the context of a business fair.

fig. 2.24 Representation of proceedings during a business fair

2.3 PRODUCTION METHOD

Umincorp's technology is designed to process large amounts of waste. Applications that process large amounts of material are most interesting when looking for suitable output markets. Commonly used production methods for mass produced plastic products that this chapter will look into are: injection moulding, blow moulding, rotation moulding and extrusion. A lot of applications found for HDPE and PP are produced by these methods. The goal of this exploration is to decide which production method and material will be a suitable starting point for the development of a product.

- Which possibilities can be seen for different types of production methods?
- Which production method is an accessible starting point for Umincorp?
- What are distinctive features that the chosen production method can produce?
- Which production method will be used?

2.3.1 EXPLORING OPPORTUNITIES

INJECTION MOULDING

Possibilities for using recycled PP and HDPE for injection moulding were researched in cooperation with Mafa injection moulding in Delft. The goal was to gain insight in; the injection moulding process, adding flakes directly instead of granules, colour effect and resulting product quality.

The test product was a simple keychain that includes a living hinge and a closing connection as product features. Specifications of the PP are: +- 90% purity and an MFI of 8. The HDPE batch obtained from bottlecaps has a purity of 99% and an MFI of 3.8. Both materials resulted in successfully produced key chains. Because of the relatively low MFI, HDPE asked for more fine tuning of the machine than PP. In practise a material with a higher MFI would be preferable.

The products were reviewed by two injection mould experts at Mafa and by one expert from Promoulding. Some imperfections where noticed and can be seen in fig. 2.28. Delamination due to impurities and excessive warping was looked for but not found. Sink marks, a weak hinge and warping can also be overcome by creating a better design or mould. During this test is was underlined once more that PP is specifically good for producing living hinges. A PP hinge should not break to easily.

fig. 2.25 flakes directly fed into the hopper

fig. 2.26 Injection moulding in process at Mafa

fig. 2.27 material from left to right: virgin pp, UMC PP, UMC PP with orange pigment added, UMC PP with black pigment added, UMC HDPE from bottlecaps.

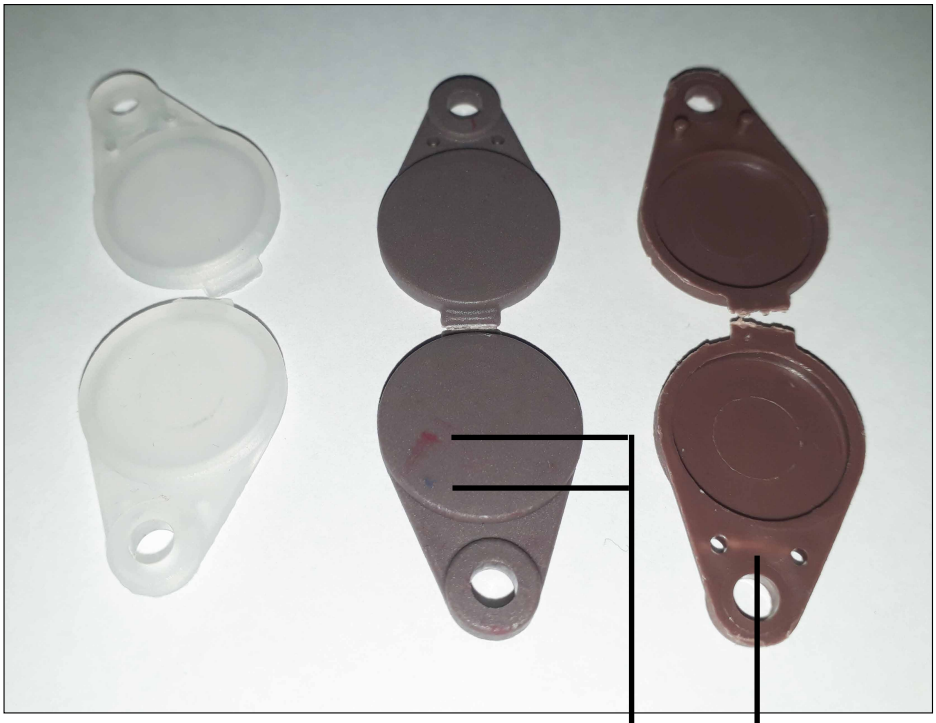


fig. 2.28

Colour difference due to the direct use of flakes

Overall colour effect due to the mixing of colours

Sink marks, could be overcome by optimising the mould

Living hinge breaks easily for both the virgin and recycled key chain

BLOW MOULDING

According to Umincorp a lot of the HDPE from household waste consists of material with a low MFI used for blow moulding products like shampoo or washing detergent bottles. Euromoldings, a producer of blow moulding products, was contacted to review possibilities for using Umincorp's material. Euromoldings stated that:

''Impurities make it difficult to use household waste, even with a purity of 99%. A single impurity can already cause a leak. Inner layers for multi-layered product could be an accessible starting point to utilize this material''

Blow moulded products produced with recycled plastic that are available on the market where looked into as well. Ecover and Head and Shoulders have bottles that consist of respectively 10% and 25% ocean waste. Seepje uses 97% household waste, this is made possible by creating a suitable high quality compound in cooperation with QCP (Seepje, 2018).

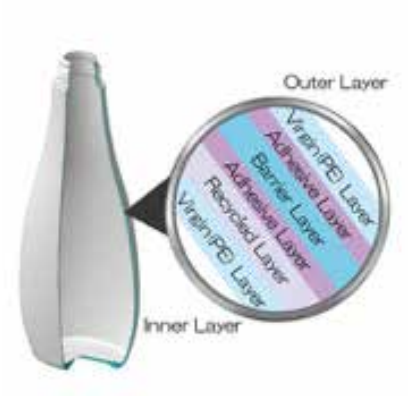


fig. 2.29 Multilayred blow moulded bottle

fig. 2.30 Head and shoulders and Ecocver bottles

ROTOMOULDING

Zweva rotomoulding was contacted and asked to test Umincorp's material. The HDPE from bottlecaps had the most promising specifications due to its MFI.

Rotomoulding uses powder instead of granules to create a product. In order to test Umincorp's material for this production method, powder needed to be made from the flakes. Zweva organised to make powder from Umincorp's material in cooperation with a specialised pulveriser. The material was accepted and successfully turned into a usable powder. Followed by this, Zweva produced a test product with the powder as can be seen in fig. 2.31. The test product shows a lot of deformation due to a relatively high density of the used material. This makes it difficult to use this material for production of a quality product.

''Inside layers in multi-layered rotational moulding could be an interesting starting point for the utilization of this material''(Zweva)

fig. 2.32 HDPE material deliverd to Zweva (left) and pulvirised into powder (right)

fig. 2.33 Outside (top) and inside (bottowm) of the test product

fig. 2.31 Test product by Zweva with Umincorp's HDPE

EXTRUSION

Extrusion can be used to create foils, sheets and semi finished products for other production methods like vacuum forming. Possibilities for the extrusion of Umincorp's material were looked into by an extruder of foils called Plastirol. Plastirol examined a batch of the PP and concluded that there should be possibilities to process the material. News about these results where received in week 12 of the project. A choice for a production method was already defined in week 8, so the results where not explored for this project. The contact with Plastirol was handed over to Umincorp, so they could continue further exploration.

ANALYSIS

The choice for a production method will depend on the possibilities of Umincorp's material and the suitability for developing a product within this project.

The non-food packaging market looks promising for using more recycled material. A lot of non-food products like shampoo bottles or washing detergent are produced by blowmoulding. However, due to the sensitivity of blowmoulding it will ask for a compounding step to create suitable homogenous granules. Within the course of this project this will be a difficult step to take, because it adds an extra stakeholder (a compounder) and asks for external development time.

Like blowmoulding, rotomoulding also shows opportunities for multi-layered products. This is still a technique that is developing and will need more time before it can be implemented. Next to this, multi-layered products also add new challenges for optimizing the recycling process of these products. The possibility to make powder directly from the flakes does make it more accessible to use it for classic rotomoulding products as well. However, specific specifications like material density should be compatible to make a product of desirable quality. The available material for this project causes a lot of deformation because of its relatively high density

Looking at the feasibility to create a product for this project, injection moulding of PP looks most promising. By adjusting settings, like pressure and head, the production process can be tweaked to get a desirable end result. For blow moulding and rotomoulding this fine-tuning has less freedom because the end results rely more on the required material specifications. This gives injection moulding an advantage when compromises have to be made for the choice between available material specifications.

2.3.2 CHARACTERISTICS OF INJECTION MOULDING

This chapter gives an overview of some basic characteristics of the production process and typical features that can be created by this production method. Injection molding is used in a wide variety of products like; consumer goods, packaging, technical parts or medical applications. Including these features in the product that will be developed for the assignment is a way to address designers or producers for these kinds of products. This could result in direct examples of relevant product features produced by Umincorp's material.

fig. 2.34. Examples of injeciton moulded products

Typical injeciton mould features:

- Snap fits
- Screw threads
- Seals
- Multiple parts in one mould
- Gears
- Embossing/debossing
- Ribs
- Removable / tearable parts
- Living hinges
- Different texture finishes
- Stackable parts

Basics of injection moulding:

- Material needs a high MFI 10-50
- High investments due to mould costs
- High volumes
- High precision
- Limited processing steps
- Diverse range of products

- Low volume < 10.000 parts
- Mid volume 10.000 – 750.000 parts
- High volume > 750.000 parts

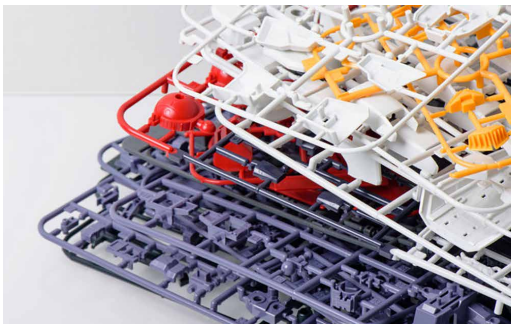
(Rodongroup, 2016)

SNAP FITS

SCREW THREADS

SEALS

MULTIPLE PARTS IN 1 MOULD

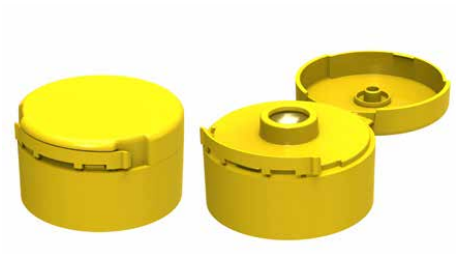


GEARS

EMBOSSING/DEBOSSING

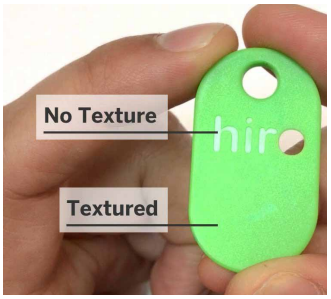
RIBS

REMOVABLE / TEARABLE PARTS

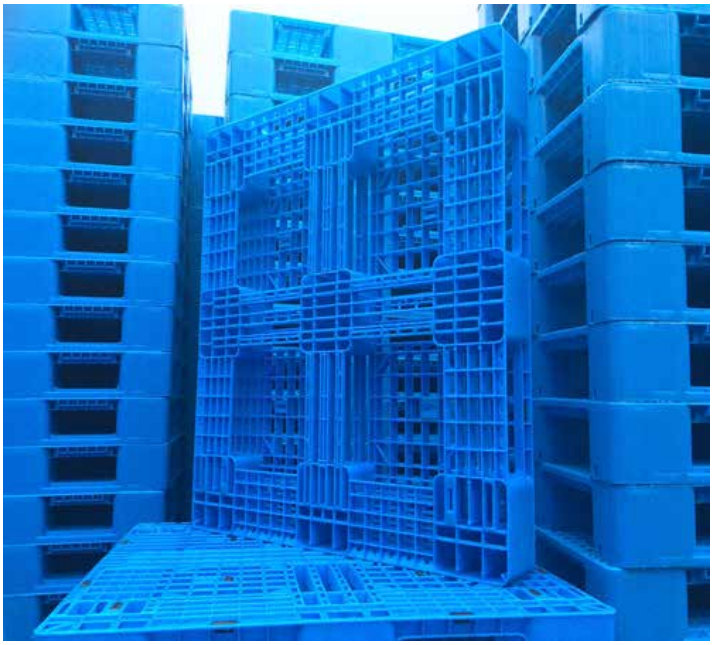


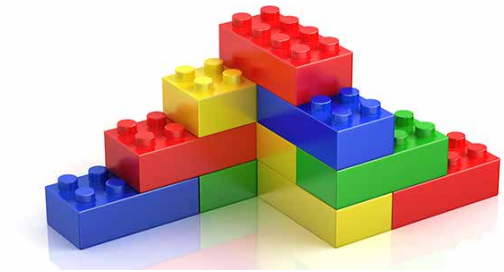
LIVING HINGES

TEXTURE FINISHES



STACKABLE PARTS





Conclusion D.A. 3: PRODUCTION METHOD

The development of a product for Umincorp will focus on injection moulding using the recycled PP material stream. Injection moulding can be used to develop a product that can address a range of producers and designers of different types of products. With the available material this production process also looks the most promising when trying to successfully develop a convincing product for this project. The wide range of features that can be obtained by injection moulding make it an interesting starting point for Umincorp to learn about different possibilities to utilize their material for product development.

- More accessible to successfully produce a product by adjusting machine settings while keeping the same material specifications than blow moulding or rotomoulding.
- A compounding step can be skipped by using the flakes directly
- Possibility to test a wide range of product features during the development of the product.
- Injection moulding is a classic example of mass production.

fig. 2.35 recap of possibilities for the different material streams

2.4 REALISATION

This chapter will look into the possibilities to realise an injection moulded product that will help convince producers and designers of the value that Umincorp's material has to offer. The following questions will be looked into to come to a conclusion:

- What investments in time and development costs can be permitted?
- Will Umincorp work together with a partner?
- When can the product be realised?

2.4.1 INVESTMENTS; TIME AND COSTS.

Umincorp has indicated that there is a not a precise budget for this project. Employee costs has been set for a total of €2700 and potential prototyping costs in the range of a couple thousand euros could be made available if there is a clear product proposal. Higher investments needed for bringing a product to the market will be considered if a clear image can be given of how these investments can be earned back. Material costs can be neglected for the first +- 500 kg of PP. This material made available for the project is a left over from an earlier processed batch.

Umincorp stated in their original assignment (Appendix 1) that the time to market is essential. The MDS system is currently based in Biddinghuizen. This will be moved to a new recycling facility in Amsterdam before the summer of 2019. From this moment a steady output of material can be realised. This also asks for a steady demand of recycled material. The product from this assignment should contribute to increase this demand. A suitable delivery date for the product will be around the opening of this new recycling facility. The PRS fair is on the 10th and 11th of April 2019, this is set as the deadline for presenting the product for the first time in public.

2.4.2 IDEATION; PRODUCT DEVELOPMENT

Two possible outcomes where taken into account during the ideation:

1. Work together with another company to develop a product.

This option would save time and costs and could even bring a product to the market. Moulds from an existing product could for example also be used.

Because of the limited time during this project, the first choice was to find out if any companies where willing to work together.

2. Develop Umincorp's own product

This option will generally take longer to realize and investments will be higher due to the costs of a mould. Next to this, Umincorp is not selling any products at the moment, just material.

Developing a product from scratch would result in more hands on experience and insight when designing a product from their material.

WORKING WITH ANOTHER COMPANY

This page shows some of the ideas for developing a product with another company.

fig. 2.36 Albert Heijn

AH would be an interesting company to work with. They also sell a lot of products under their own name. Next to this they are trying to become more sustainable and have a campaign about sustainable packaging (Ah, 2018). Non-food injection moulded packaging or their shopping basket could be interesting options.

fig. 2.37 FLUX

The designer of flux chairs used to study at the faculty of IDE. A nice example of an interesting plastic product. Unfortunately the PP used for this chair is very specific and Flux does not see possibilities for using Umincorp's material.

fig. 2.38 Greentom

Greentom already has products from recycled household waste. This is an interesting partner to develop more products with. Unfortunately Greentom is a partner of QCP and is not available for working together with Umincorp.

fig. 2.39, 2.40 APE Design Amsterdam
Design bureau Amsterdam APE, Walter Wallet, Kuipstoel: Walter Wallet geproduceerd bij.. Kuipstoel china
A nice consumer product is the Walter Wallet by APE design. This product is produced at Naber in the Netherlands and APE would be interested in producing this product from recycled plastic. They also have a chair called the 'Albert Kuip stoel' that they would like to see in recycled plastic. ''The Albert Kuip stoel made from recycled plastic from Amsterdam''. This chair is unfortunately produced in china which makes it more difficult to develop.

fig. 2.41 Impression of coloured products from recycled plastic

fig. 2.42 LUSH
Colour sorted recycled plastic used directly for production could result in an interesting colour pallet. The limitations in colour use can be turned into a strength. More natural colours fit the modern sustainable trends. A company like Lush would be an interesting partner, because they already focus on recycling and using less packaging (Lush, 2015).

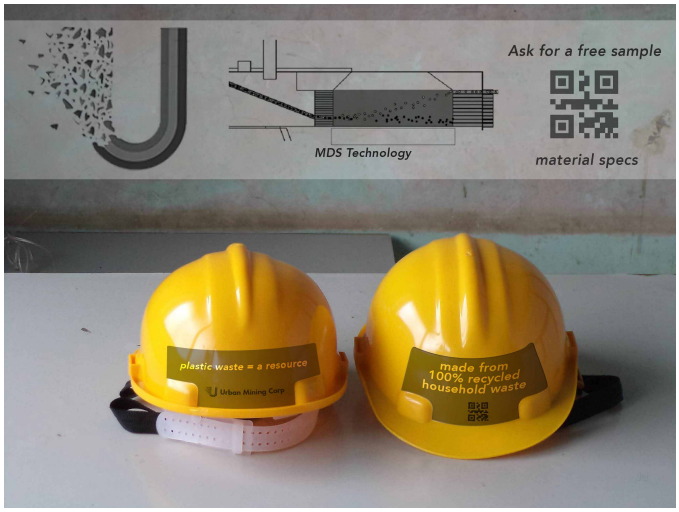


fig 2.43 ideation helmet from recycled plastic

CONSTRUCTION SAFETY HELMET

A safety helmet was another idea for the development of a product in cooperation with a company. This is a product that can translate quality of the material in a clear and qualitive way. It has to go through standarised test. When the product is designed to pass the tests sucesfully, it will officially qualify as 'quality product'. Appendix 9 gives more information about this concept proposal.

The first step to develop the industrial safety helmet was trying to find a partner that has access to a mould for this product. It could result in a product that will be sold under the name of a quality PPE brand. Unfortunately, during this project no companies where found that were willing to work together to develop a helmet made from recycled PP. Buying a mould would be another option to realise this project. Standardised moulds that are made in China would cost around €25.000-€30.000 (Promoulding, 2019).

fig 2.44 ideation helmet from recycled plastic

fig 2.45 Example of a quality Personal Prodtection Equipment brand

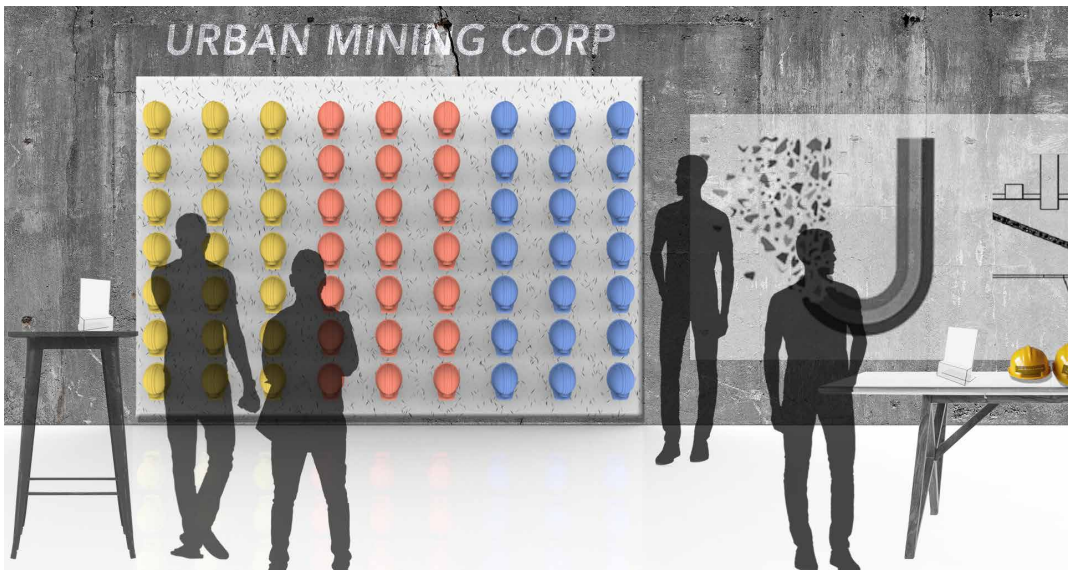


fig 2.46 representation of the helmets in the context of a business fair

Conclusion D.A. 4: REALISATION

Umincorp is interested in the proposal of a construction helmet. However, they indicated that in order to make investments this high, certainty for an output market should be established first. According to the assignment, the goal of this product is to convince people of the quality of the plastic, not bringing a product to the market in large quantities. Instead of establishing a market, or keep on trying to find a partner, the option for developing a new product was chosen.

A relatively cheap and fast way for doing this is by using a 3d printed mould for injection moulding. These moulds can produce batches of 50-100 products and range in price between €1500 to €3000 for development and production of the products. Umincorp indicated that this is a suitable amount for the purpose of this project. Maximium dimensions of products suitable for this method are: 200 x 200 x70 mm. Development and production of the mould and products can be done within 5 days (P3d, 2018).

The moulds are printed using polyurethane that hardens under uv-light. This technique is relatively new and is a great way of bridging the gap between digital prototyping and fine-tuning of a real mould. For virgin plastics this is already used to save time and development costs. Recycled plastics have due to their characteristics more unpredictable specifications than virgin plastics. Prototyping with a printed mould could be a relatively cheap and fast way to learn more about the behaviour of the recycled material for injection moulding.

Injection moulding of a small product batch in a 3d printed mould:

- Assignment asks to convince potential customers, this does not specficically mean bringing a product to the market succesfully.
- Lower investments in time and costs
- 50-100 products is a suitable amount for this project.
- Flexiblity of prototyping
- Interesting learning curve for Umincorp

fig. 2.47 3d printed mould for injection moulding

2.5 DESIGN BRIEF

This design brief further defines the assignment in the project brief of chapter 1.1. Decisions areas 1 till 4 are translated into design challenges that are used for the development of the concept proposals. A product vision is described to gain a better understanding of the direction for the product development.

DESIGN CHALLENGES

D.A. 1:
- Give insight in the price of recycled PP from Umincorp.
- Show the result of how high purity recycled material influences product features.
- Breach negative preconceptions about the inferior quality of recycled material.
- Show possibilities of the development for colour separated recycled plastics.
- The product should help to make specification sheets more accessible.
- The product should fit the idea of circular product design.

- The product should function within current regulations about recycled plastics.
- Availability of constant material specifications should not be of key importance for the type of product that will be developed.
- The material should be used for production without having to compound it.
- The characteristics of the recycled material should not obstruct the product its function.

D.A. 2:
- Gain the attention of injection moulding producers and product designers.
- Design a product suited to present in the context of a business fair.

D.A. 3:
- Produce a product using recycled PP from Umincorp.
- Design a product suited for injection moulding

D.A.4:
- Develop an injection moulded product whitin limited time and funding
- The product should fit the requirements for production in a 3d printed mould.

PROJECT VISION

Bringing another, possible luxury plastic product, to the market is ecologically speaking not helpful. Directly using the material for currently indispensable larger scale applications would be more desirable. Unfortunately, previous experience with recycled plastic by producers and designers often showed that there are many issues to overcome. Because of Umincorp's MDS technology, new opportunities are opening up. Plastic recycling is in a transitioning phase aiming towards a circular system with quality materials. Preconceptions from previous experiences need to be breached in order to get this material to larger scale operations.The product itself shows possibilities for using the material and acts as inspiration for other applications to do the same. Only a small quantity of this product will be produced. It is a means to an end.

For producers and designers of injection moulded products,
who need to be convinced of the value that Umincorp's material has to offer,
the product should show that a quality product with typical injection moulded features can be realised when the right sorting technologies are applied.
Unlike the virgin version of this product,
the product sets an example for utilizing waste as a valuable resource that helps to lower the ecological impact of plastic products by expanding the material's lifespan.

3.

PRODUCT DEVELOPMENT

This chapter will focus on the development of different concept proposals for Umincorp. The ideation tries to find answers to why a certain concept is relevant and should be developed. Each concept proposal will be compared to the other proposals and a decision for the most promising option will be made. The chosen concept will be developed further and a list of requirements is composed to define the final design. An embodiment process can be found that explains the design decisions that were made to come to the final design that is presented at the end of this chapter.

CONTENT

3.1 CONCEPT PROPOSALS

- What kind of products fit the design brief?
- Why should the specific product be developed?

Three different concept proposals where composed in order to explore different ideas for a final product. The most important product categories that came up during the ideation are summarised in fig 3.2. User experience of the product is defined using the human experience catalog (Emotion.studio, 2018). The evaluation of these emotions will be conducted during the interviews in chapter 4. The different concept proposals where compared and a final product direction was chosen that was going to be developed further.

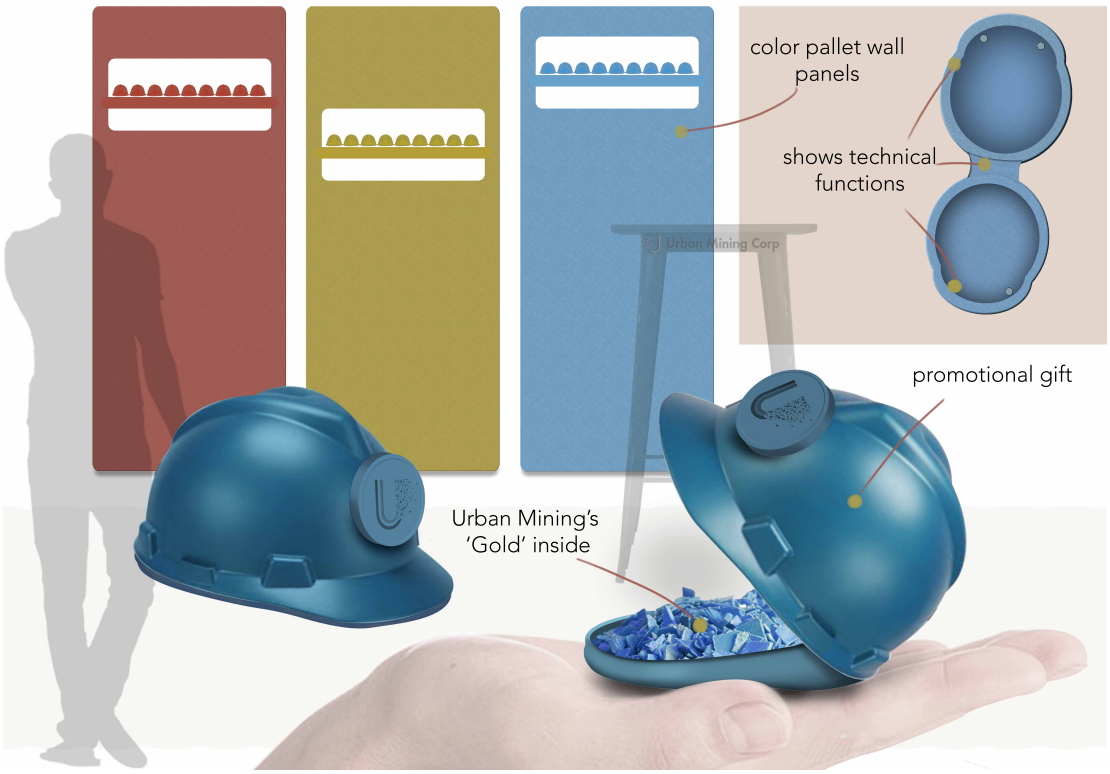
fig 3.1 CF students brainstorming for product qualities, experience and concepts.

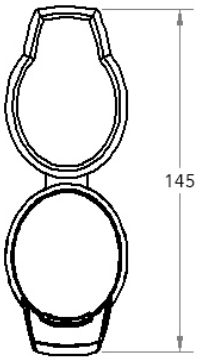
fig 3.2 Ideation route for products on a business fair

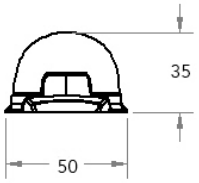
A succesful design of the cardholder could trigger the following positive emotions:

fig. 3.3 Source: Pieter Desmet & Steven Fokkinga / emotion studio, Human experience catalog

MINING HELMET PACKAGING

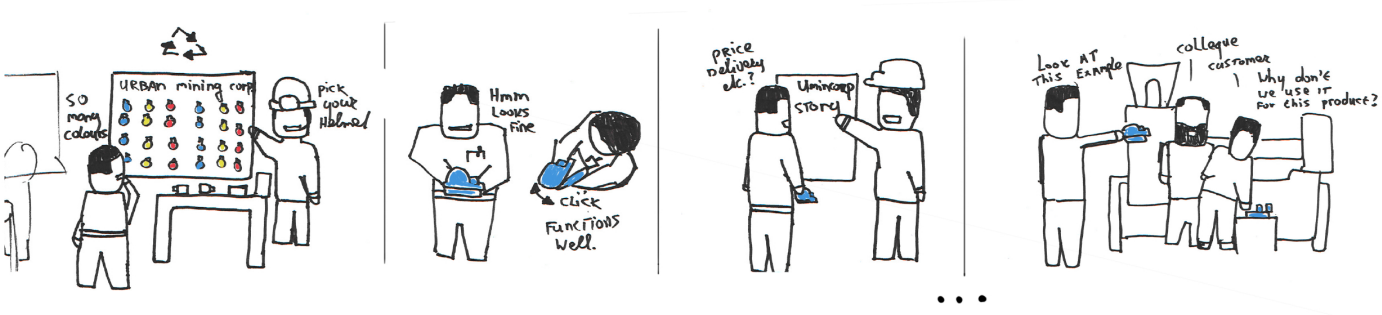






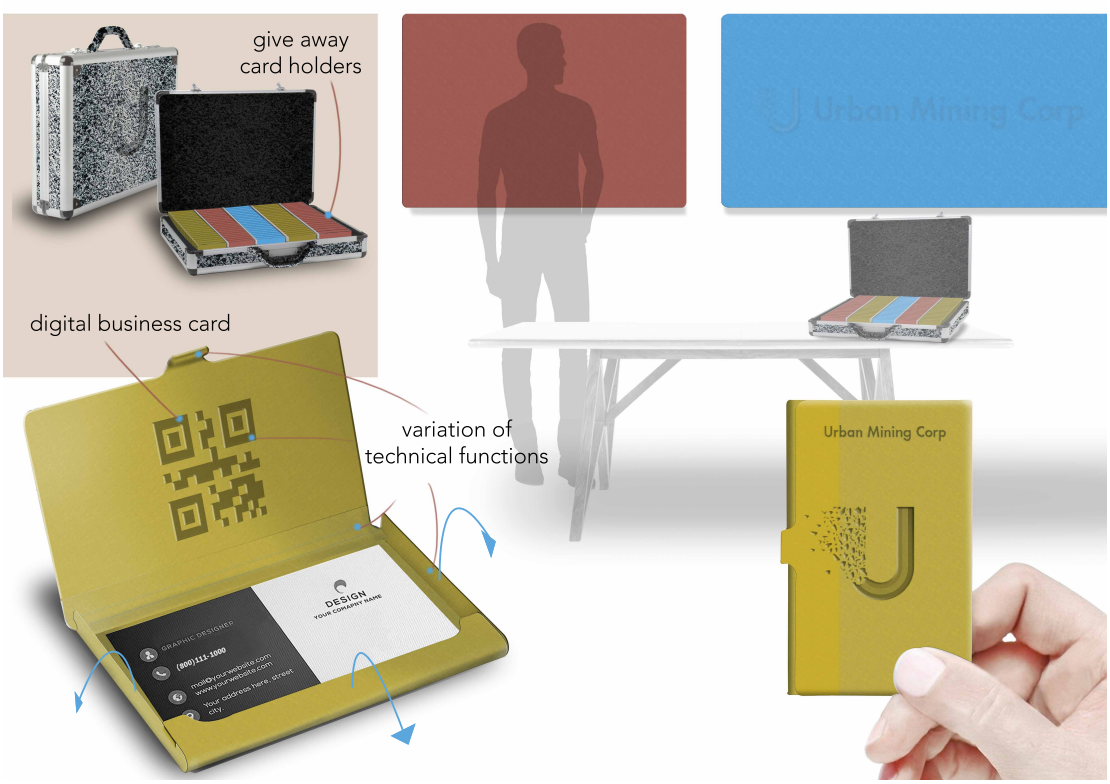
This is a give away product for potential customers that shows them the possibilities of the material. The product gives direct examples of material qualities that are relevant to non-food packaging. A living hinge and a click connection make it a functional packaging that contains a small sample of Umincorp their material. This sample shows pure, clean and colour sorted plastic instead of the usual mixed, dirtier looking recycled plastic. The design of the mining helmet is a link to a strong trustworthy product and to the company its name; Urban Mining Corp.

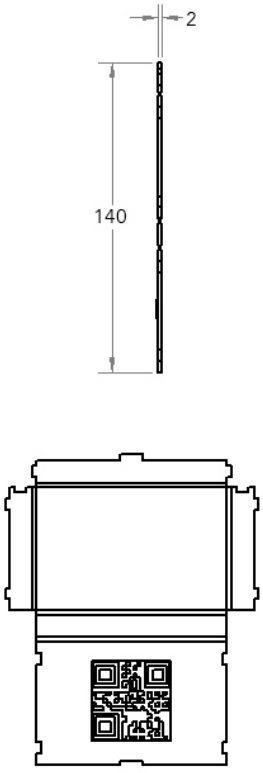
Usps	To be developed
Direct link to the packaging industry.	Function.
Reference to urban 'mining'.	Way of presenting it.
Something to take home.	Translation of additional material qualities
Unique fun product.	Link to spec sheets & price



gain attention *show qualities* *inform about Umincorp* *spread the word*

BUSINESSCARD HOLDER



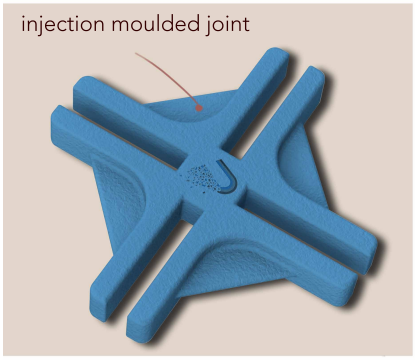


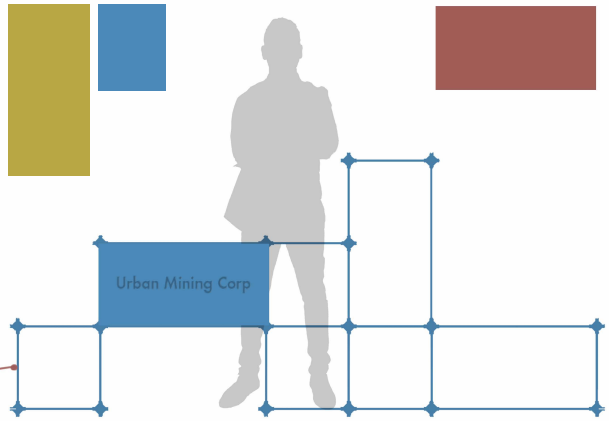
Business cards are still a conventional way to expand your network and create new business relationships. A cardholder for the different cards you get at business fairs is a relevant and useful product to give away to potential customers. This foldable cardholder shows technical qualities of the material it was made with. Next to storing cards, this product also serves as a business card itself. The detailed QR code can be scanned to take you directly to Umincorp their website. At the same time this code shows the possibilities of creating fine details with the material.

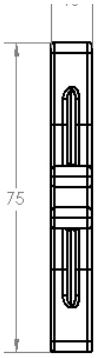
Usps	To be developed
Useful product for business relations. Clear overview of product qualities. Something to take home. No nonsense.	Translation of additional material qualities; handling of different forces. Way of presenting it. Refined Aesthetics.

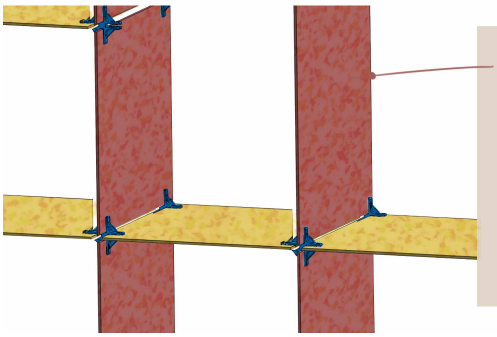
exchange business cards *show qualities* *reminder when used* *conversation starter*

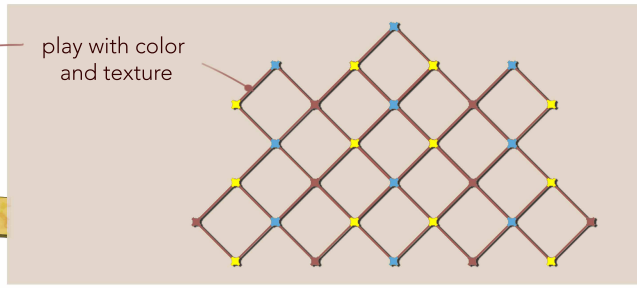
JOINT FOR MODULAR STAND

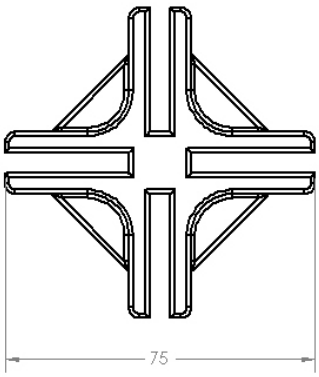






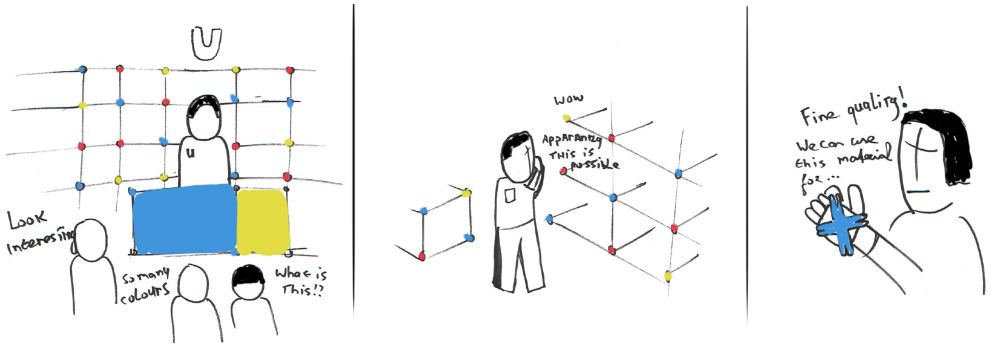






This joint can be used together with sheet material to create a modular business stand. Strength and toughness are crucial for a part like this. Creating a stand out of recycled plastic should show that this material could be used for an application that can withstand these forces. The sheet material will be made from plastic as well to create a uniform product. Pressed sheets from recycled plastic leave open the opportunity to play with textures and colour gradients. Playing with different colours and textures can make this product an eye catcher on the sometimes more sober business fairs.

Usps	To be developed
Lasting function	Sheet material.
Unique object for business fairs.	Tolerances.
Translates the product's ability to withstand different forces.	Translation of additional material qualities;
Breaching negative preconceptions about lack	surface finishing, details, living hinge.
of colour in recycled plastics.	Refined Aesthetics.
Product forms 1 unified whole.	



eyecatcher *surprise about qualities* *inspiration*

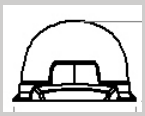
3.2 CONCEPT CHOICE

A decision for the development of the final concept will be made here. Wishes from the list of requirements (chapter 3.3) where used in a weighted obejective method to compare the concept proposals to each other. These whishes are defined as characteristics for the most convincing concept.

Mining helmet		Card holder		Modular joint	
mould/production cost estimation		**mould/production cost estimation**		**mould/production cost estimation**	
Batch size	Costs	Batch size	Costs	Batch size	Costs
50	€2300	50	€2100	50	€1800
100	€2700	100	€2500	100	€2200

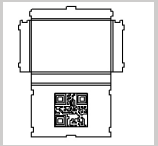
fig: Price indications given by P3d

Weight	
25	Material qualities are translated in multiple ways
15	The product has a useful function
15	The product is accessible to develop due to simplicity of technical functions
15	Next to business fairs, the product can be used in multiple contexts
10	The product is suitable to fit Umincorp's image as a company
10	The product stands out in the context of a business fair
5	The product particularly gives a clear example for producers of packaging products
5	The product has a long functional lifespan
100	



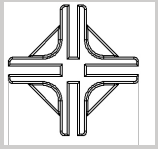
Helmet packaging

Score	Total
8	200
4	60
8	120
6	90
7	70
7	70
9	45
3	15
	670



Cardholder

Score	Total
8	200
7	105
8	120
8	120
9	90
6	60
8	40
8	40
	775



Modular joint

Score	Total
4	100
8	120
4	60
5	75
6	60
8	80
3	15
7	35
	545

Conclusion D.A. 5: PRODUCT DEVELOPMENT

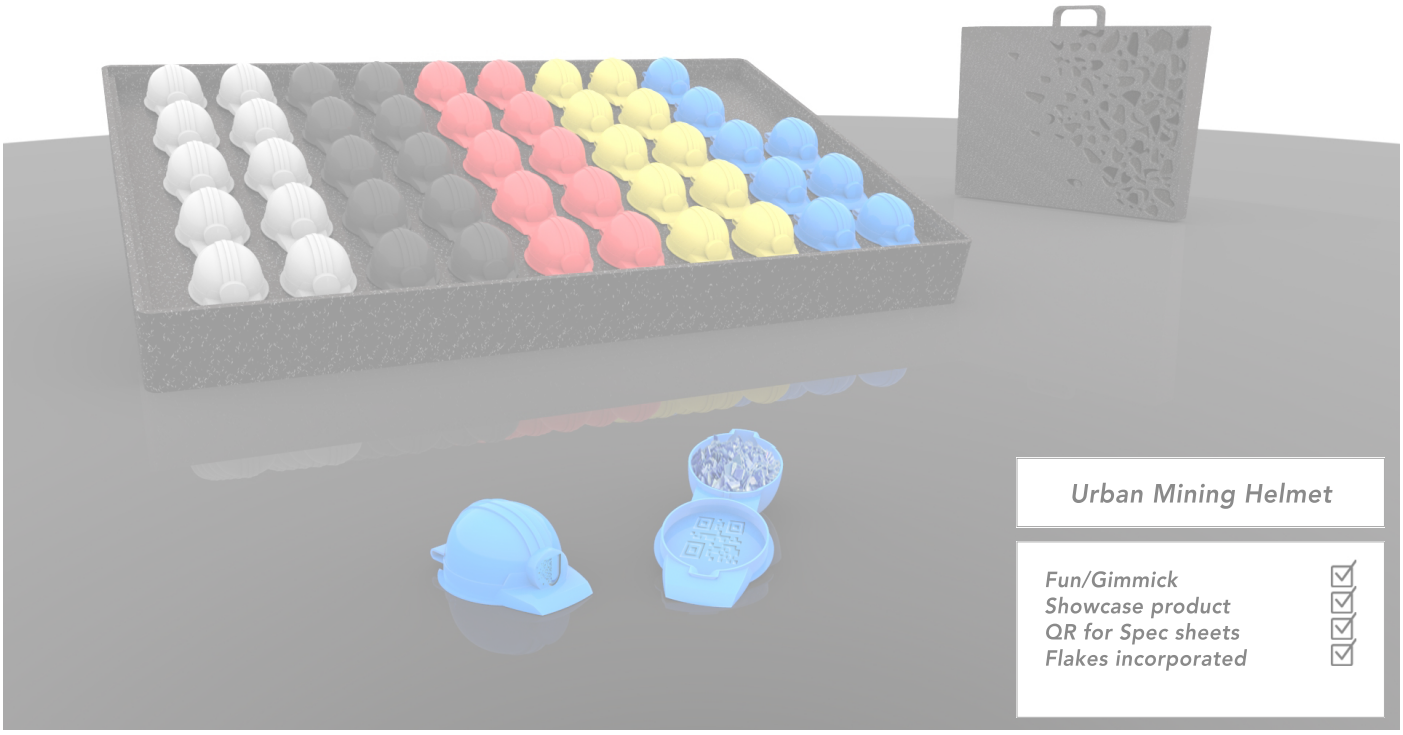
Compared to the modular joint, the helmet and cardholder both score high on wish number 1. The modular joint could be improved on this wish. Adding a living hinge to the design will create an opportunity to, for example, add doors to the stand. This will however make it an even more challenging part to develop. A modular stand could become a product that is an eye catcher on a business fair. However, there are still many unsolved issues related to tolerances between the joint and sheets and managing the mechanical forces of the stand.

The helmet packaging and business card holder are more similar to each other than the modular joint. Overall, the helmet has a lower score because it does not have a clear function besides being a show case product. The design is supposed to be a gimmick for urban mining. For some people this can be fun and catching, but in more serious settings like business fairs or meetings, this could also be seen as distracting or childish. Within the topic of sustainability it would also be inappropriate to create a give away product with a very short lifespan. Based on these observations and the outcome of the weighted criteria the cardholder will be developed into a final concept.

''The business cardholder''

- '' '' can be a useful relationship gift that has a clear function during a business fair or other network occasions.
- '' '' Is, within the goal of increasing their knowledge and network, a relevant product for Umincorp's own employees as well.
- '' '' can translate multiple material qualities into functional features.
- '' '' can become an elegant product that Umincorp or potential partners can relate to.

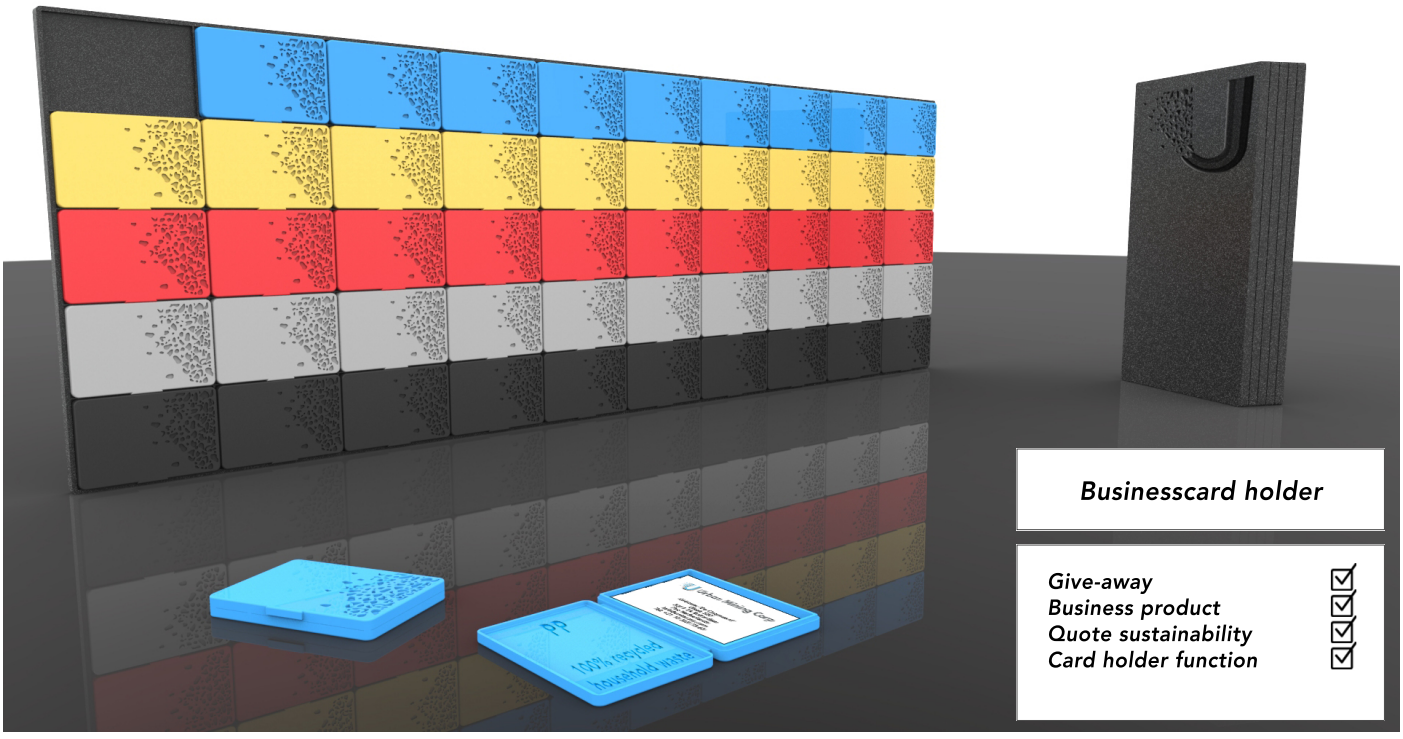
More decisions about functionaly and easthetics will be decided on in the following chapter. The final concept in chatper 3.4 will give an overview of the result of the product development.



Urban Mining Helmet

Fun/Gimmick ☑
Showcase product ☑
QR for Spec sheets ☑
Flakes incorporated ☑

VS.



Businesscard holder

Give-away ☑
Business product ☑
Quote sustainability ☑
Card holder function ☑

3.3 FURTHER DEVELOPMENT

Further development of the business cardholder consisted of defining all the specific product attributes, injection moulding features and easthetics. Existing relevant products where looked at for inspiration and a combined with as many of the injection moulding features listed in chapter 2.3.2. A list of requirements is set up that states all the important characteristics that the design should meet. These are worked out in an embodiment of the final design.

fig 3.4 Examples of existing cardholder products

FUNCTIONS

The product will be able to hold up to 15 cards, a comparable amount as similar products (Ogondesigns, 2014). Next to storing cards, more functions can be included that are relevant in the context in which the cardholder is going to be used. It was decided to include the function of a name tag into the design. Next to a functional benefit it will also make the product more visible to a larger audience. This name tag can be worn vertical or horizontal depending on the layout of the business card.

A dispenser function will be integrated for a smooth process of presenting a card to someone. This dispenser function should also result in a bigger involvement and visibility of the product into this process. Finally the design will allow the product to be used as a stand that can for example be used during meetings.

CARD SIZES

There is no official standard for dimensions of a business card. Commonly used sizes vary slightly around the world and depend on tradition or printing and storing convenience (Printplace, 2019). For example, a commonly used size for business cards in western Europe (85 x 55 mm) is related to banking cards (85.60 × 53.98 mm).

The businesscard holder for this project will be designed to hold cards up to 91 x 60 mm. With an exception of some odd shaped cards, most cards will be able to fit inside the product.

fig 3.5 Collection of businesscards arranged in different sizes

fig 3.6 Memetic collage, product form details related to the persona of designers and producers of injection moulded products

3.3.1 LIST OF REQUIREMENTS

The origin of the requirements are indicated by the blue design challenge number (D.C..)

1. FUNCTIONS

D.C. 1.1, 1.2 & 2.1 as many of the features listed in chapter 2.3.2 are included that are relevant for the cardholder.

The product should include the following injection mould features:

1a. Living hinge
1b. Embossed/debossed text/logo
1c. Multiple surface finishes
1d. Click connection/snap fit
1e. Seal
1f. Flexable function (not including snap fits)
1g. Stackable

1h. The product is produced in different colours. D.C. 1.3
1i. The product gives a link to Umincorp's website D.C. 1.4
1j. The product gives information about the material price. D.C. 1.5
1k. The product application should not interfere with current regulations about recycled plastic. D.C. 1.

D.C. 1.8, 1.10 & 2.2, the following requirements originate from the functions that are defined in chapter 3.3

1l. The product can store up to 15 business cards
1m. The product can stand up horizontally by itself
1n. Cards stored inside the product are protected from tearing or wrinkling
1o. 1 card can be attached to the outside of the product
1p. The product can be attached to a keychain
1q. The product can be clipped horizontally and vertically to a pocket or piece of clothing
1r. The product includes a dispenser function
1s. No cards can fall out while using the product
1t. Cards with sizes up to 91 x 60 mm can be stored inside the product

2. MATERIAL

2a. The product is produced using 100% recycled PP flakes from household waste. D.C. 1.9 & 3.1
2b. The product includes information about the used material D.C. 1.2

* D.C. 3.2 & 4.2, these requirements are linked to the requirements from Promolding for producing in a 3d printed mould. (P3D, 2018)

3. SHAPE/DIMENSIONS*

3a. The maximum dimensions of the product should not exceed: 200L x 200W x 70H mm.
3b. The product design should have no overhanging parts.
3c. Product surfaces with a 90 degree angle to the direction of draft, require a minimum draft angle of 1 degree.
3d. Wall thicknesses of the product should lie between 1 and 4 mm.
3e. All corners should be rounded with a minimum radius of 0.5 mm.
3f. No sink marks should be visible in the final product due to a difference in wall thickness.
3g. No visible shrinkage should occur due to the presence of large volumes in the product.
3h. No mould inserts should be needed for the design of the product.

4. PRODUCTION*

4a. The product should be produced using injection moulding.
4b. Produce a series of 50+ products.
4c. The product should be produced using a 2-part mould.
4d. Multiple parts inside the mould should have similar dimensions and volumes
4e. The mould of the product should be produced by 3d-printing.
4f. The mould of the product should have a matt surface finishing.

5. PRICE AND PLANNING

5a. The production costs should not exceed €3000

5b. The product should be ready for the PRS, before the 10th of April.
D.A. 4.1

6. SUSTAINABILITY

6a. The product should be produced only using recycled PP. D.A. 1.6

7. WISHES

7a. Material qualities are translated in multiple ways

7b. The product has a useful function

7c. The product is accessible to develop due to simplicity of technical functions

7d. Next to business fairs, the product can be used in multiple contexts

7e. The product is suitable to fit Umincorp's image as a company

7f. The product stands out in the context of a business fair

7g. The product gives a clear example for producers of packaging products

7h. The product has a long functional lifespan

7i. The form language is adapted to indented user group

7j. Minimize excessive use of material

7k. Any logos of Umincorp should be only subtlely visible

DESIGN CHALLENGES

D.A.1:
1. Show the result of how high purity recycled material influences product features.
2. Breach negative preconceptions about the inferior quality of recycled material.
3. Show possibilities of the development for colour separated recycled plastics.
4. The product should help to make specification sheets more accessible.
5. Give insight in the price of recycled PP from Umincorp.
6. The product should fit the idea of circular product design.
7. The product should function within current regulations about recycled plastics.
8. Availability of constant material specifications should not be of key importance for the type of product that will be developed.
9. The material should be used for production without having to compound it.
10. The characteristics of the recycled material should not obstruct the product's function.

D.A.2:
1. Gain the attention of injection moulding producers and product designers.
2. Design a product suited to present in the context of a business fair.

D.A.3:
1. Produce a product using recycled PP from Umincorp.
2. Design a product suited for injection moulding

D.A.4:
1. Develop an injection moulded product whitin limited time and funding
2. The product should fit the requirements for production in a 3d printed mould.

3.3.2 EMBODIMENT

The design of all the product's functions will be shortly explained. Appendix 10 gives the full embodiment design journal). The critical details of the design are prototyped with 3d printed versions of the CAD model. Click fingers and hinges can be designed for 3d printing, however the material distribution and dimensions will be different than for injection moulding. These parts of the design will have to be tested throughout the injection moulding process.

DESIGN CONSIDERATIONS

- Draft angle: P3d asks for a minimum of 1 degrees, preferably more. The cardholder has draft angles of 2 degrees.
- Undercuts: Undercuts are avoided in the design of the cardholder
- Roundings: Corners are rounded with a 0.5 mm radius
  Large flat surfaces: According to P3d, it is difficult to establish a good end result for large flat surfaces, adding curvature can help to hide potential imperfections in the shape.
- The cardholder will have a medium wall thickness of 1.5 mm. Wall thickness PP: 0.635mm - 3.81mm (Protolabs, 2018)
- A uniform wallthickness should be established to prevent accumulation of material.

CLICKFINGERS

The clickfingers are designed according to a cantilever style. This is a relatively easy design and also one of the most likely styles that is commonly used (Bonenberger, 2016).

An overhang depth of 1.5 mm (+- 70% of Y) was estimated to have enough clamping force and is encorporated in the first file that was send to P3d for the production of the 3d printed mould.

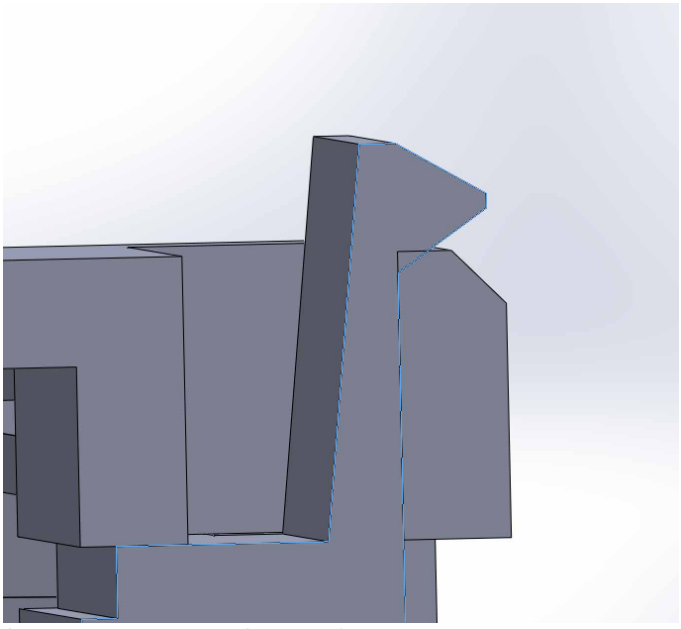


fig 3.7 cantilever snap fit in the final design

Y = permissible deflection
E = 11% (datasheet Umincorp)
E = 0.6 x 11%

Y= 1.09 (e . l^2)/ h

h= 3.5
l = 1

Y = 2.18 mm

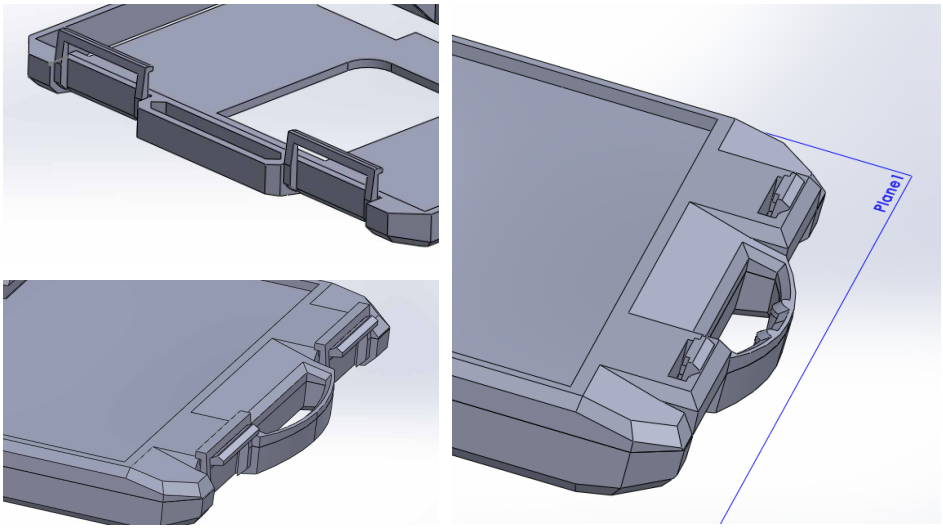


fig 3.8 Iterations of snap fit designs (final design in the right picture)

ABILLITY TO ATTACH A CARD

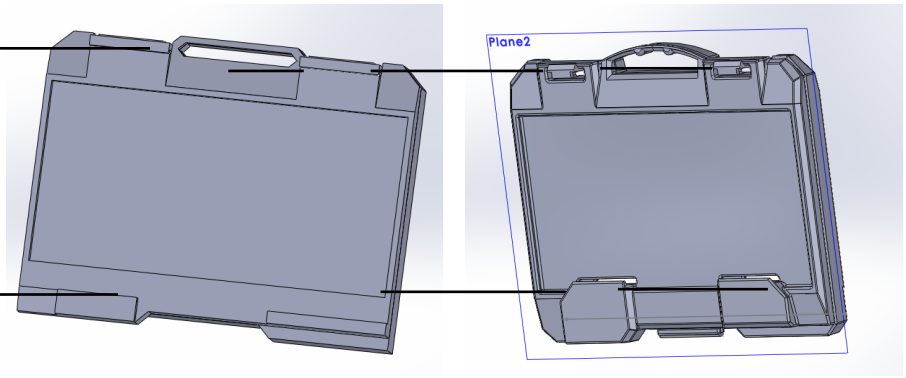


fig 3.8. placement of a card on the front of the case

The card will be hold in the following places.

A small addition to the snap fits will make them able to function as an attachment for a card as well.

To avoid undercuts, cores are added into the mold that rise up to the attachment parts.

P3d asked for a final ajustment to the model. The cores in the first model are very thin and can cause problems during production. To avoid this problem, the snap fits where moved back so the diamter of these cores could be doubled. ↔ ⟷

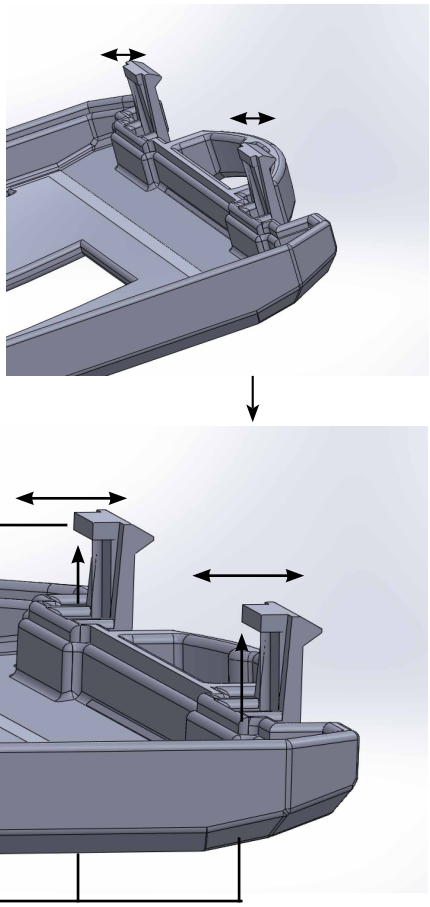
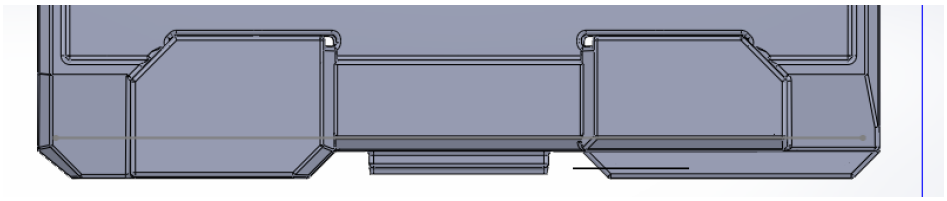
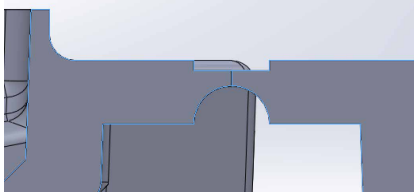


fig 3.9. Iteration of snap fit design and card placement

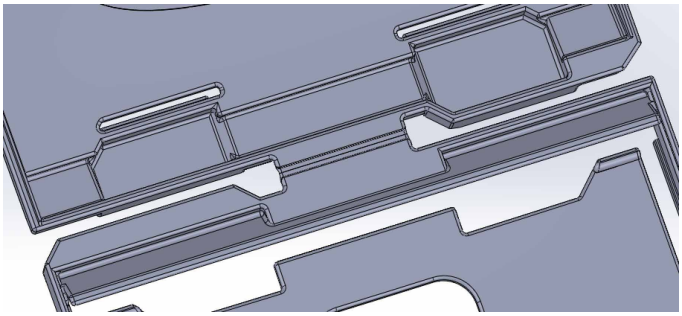
STANDING & LIVING HINGE

fig. 3.9-3.12

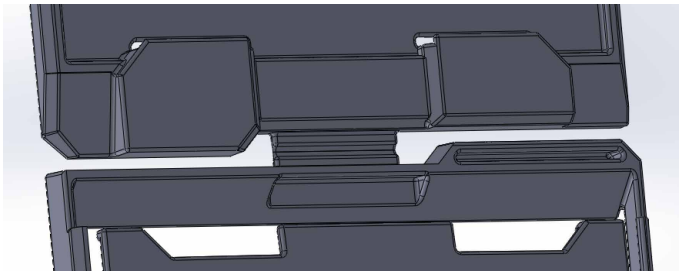




The easthetics of the cardholder are based on a toolbox for powertools. The orientation for opening a box like usually asks for a hinge on the bottom of the box instead of the side. The cardholder is supposed to stand up by itself. A hinge on the bottom makes this more difficult to create an even surface.



The following design was made: to have the hinge on the bottom, create a stable surface, even wall thickness , no openings on the front of the case and no ondercuts for moldability.



The hinge design is based on basic design guidlines for plastic hinge design (Protolabs, 2018).

DISPENSER

The dispenser should allow cards to be dispensed smoothly. The cards should not fall out of the dispenser. When there are less cards (especially only 1 card) in the case, this becomes more challenging. For this reason two small bumbs are added. These bumbs cause the card(s) to skim slightyly which helps to keep them inside the case. The final design has one smooth slope that does not influence the ability of the case to stand up straight.

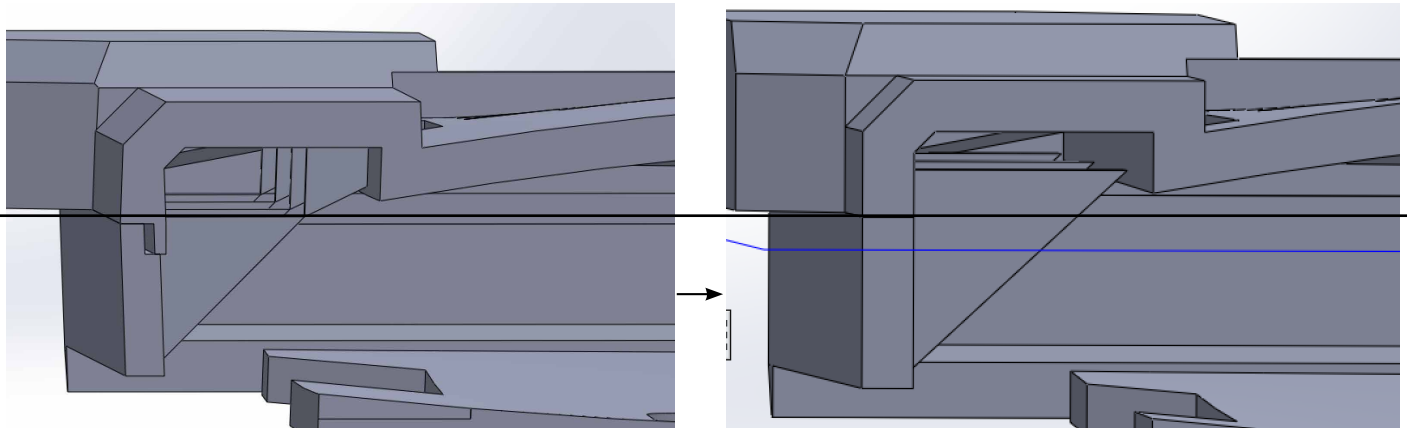
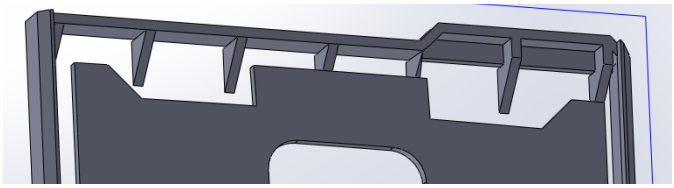
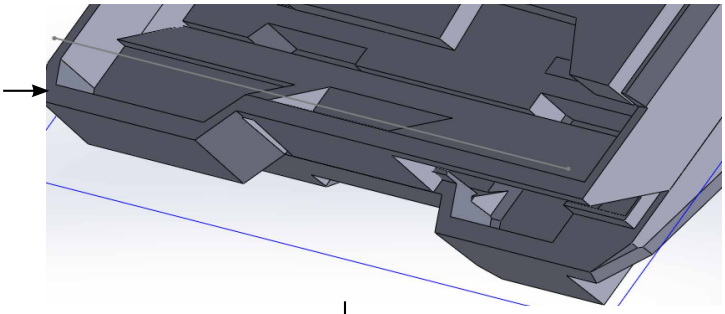
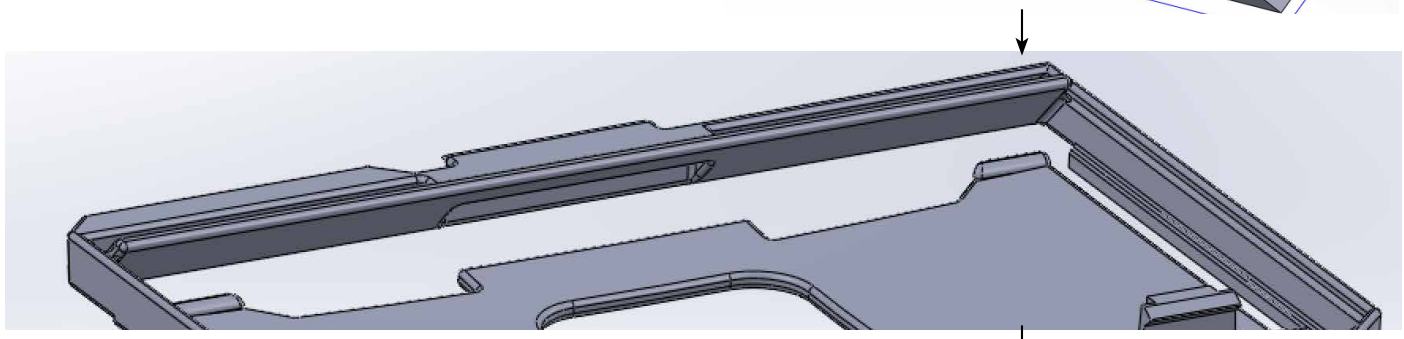


fig. 3.13 Iteration of product distribution among mould halves







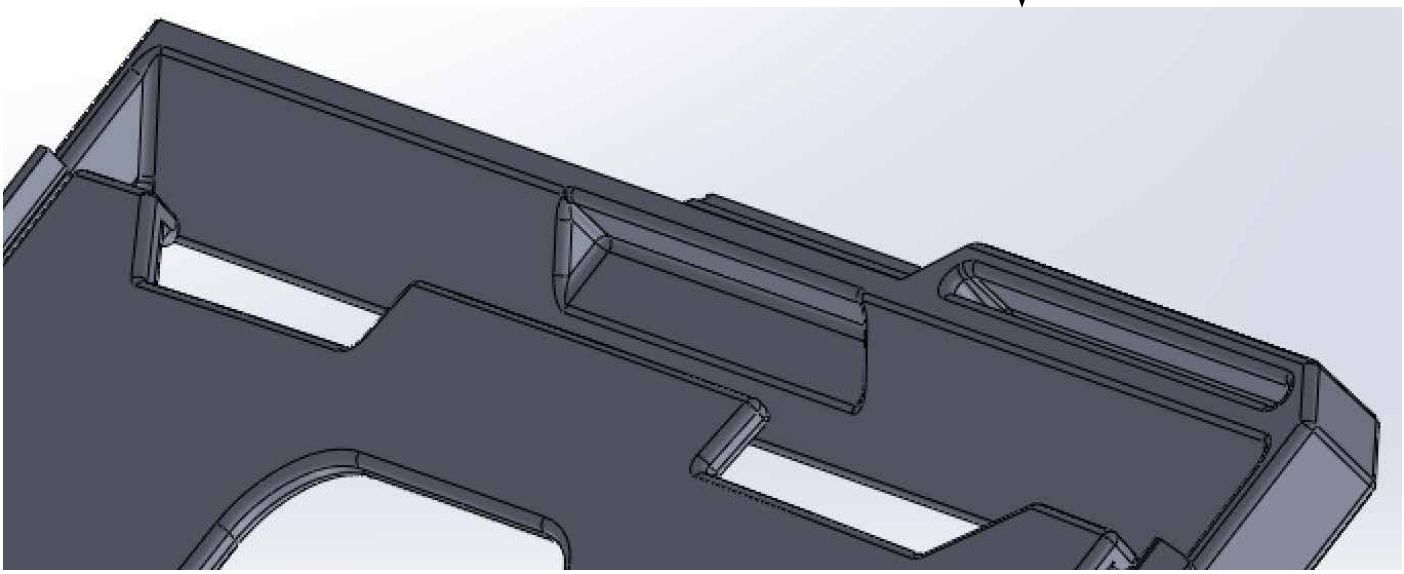


fig. 3.14-3.17 iteration of dispenser system

KEYCHAIN ATTACHMENT

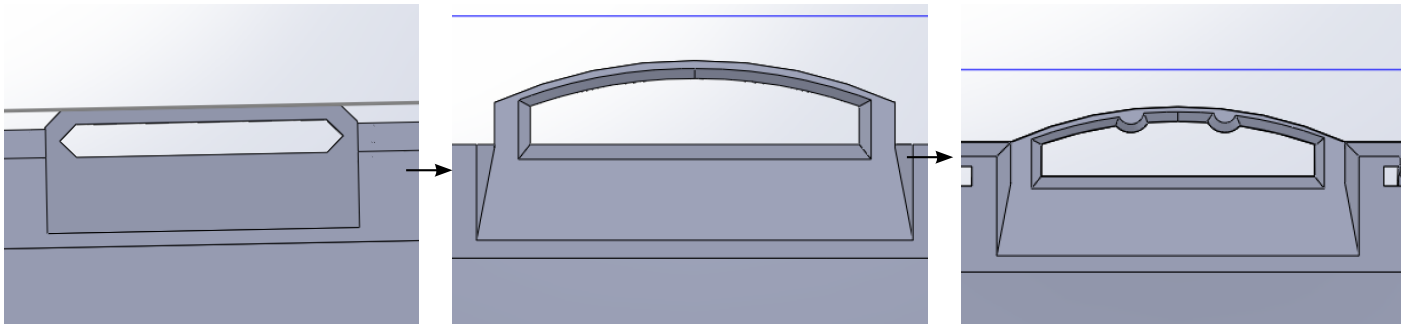


fig. 3.18 Iteration of keychain attachment

The attachment is designed to be able to be hooked to a keychain. The curvature and bums in the final design cause the carholder to hang horizontally straight.

STACKABLE + CURVE

The form of the clip at the back of the case is added as a form fit. This allows the cases to be stacked neatly. The curvature of the front and back does not interfere with the ability to stack the cases on top of eachother.

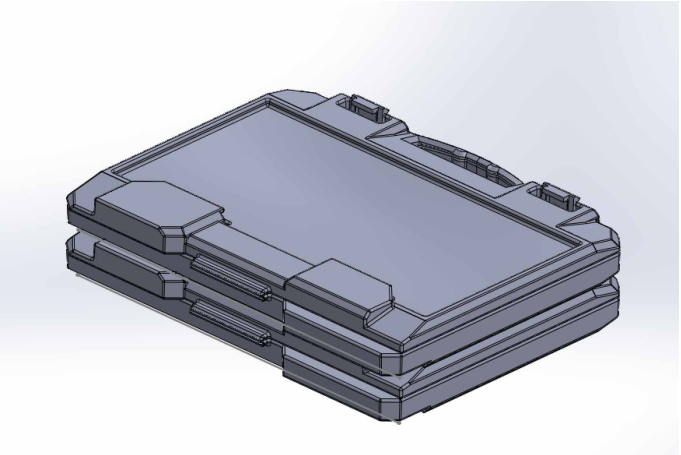


fig. 3.19 stacked cases

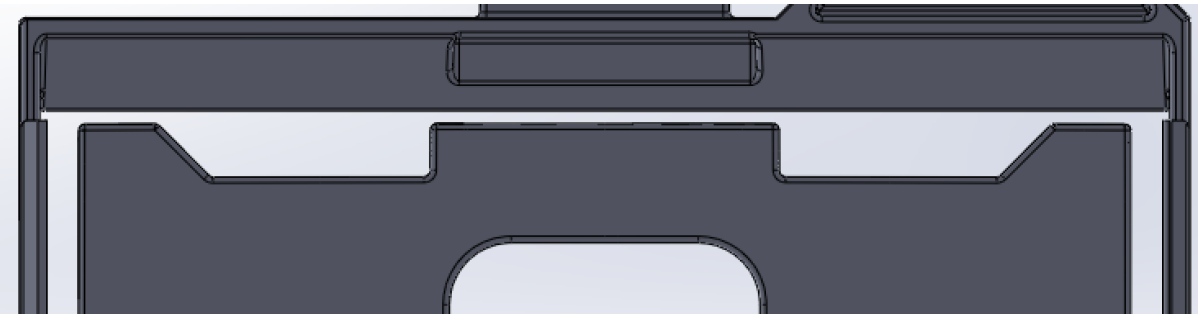
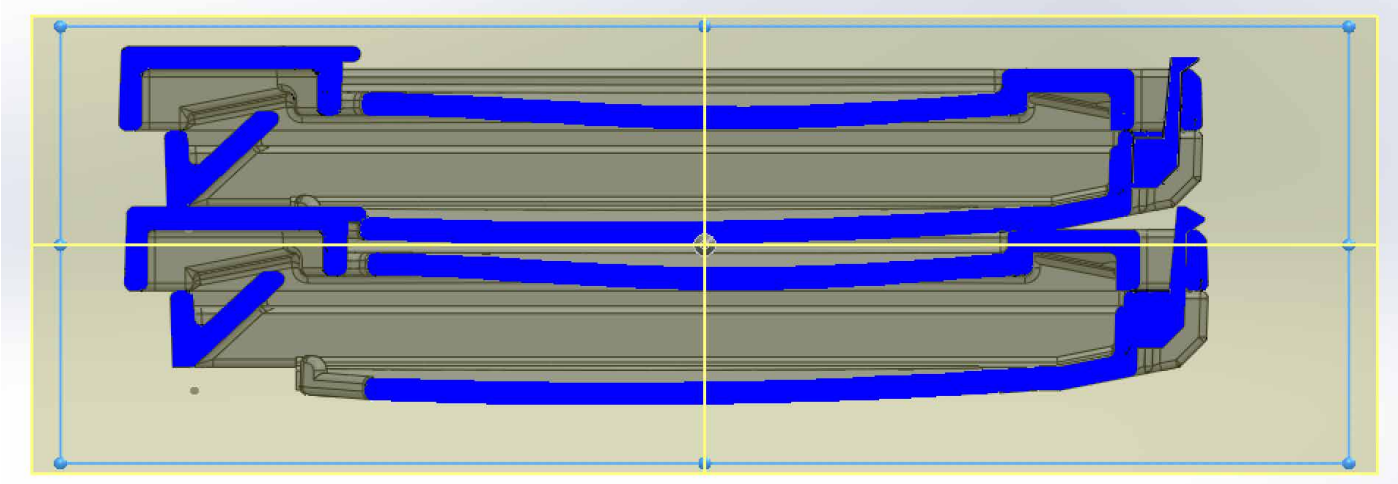


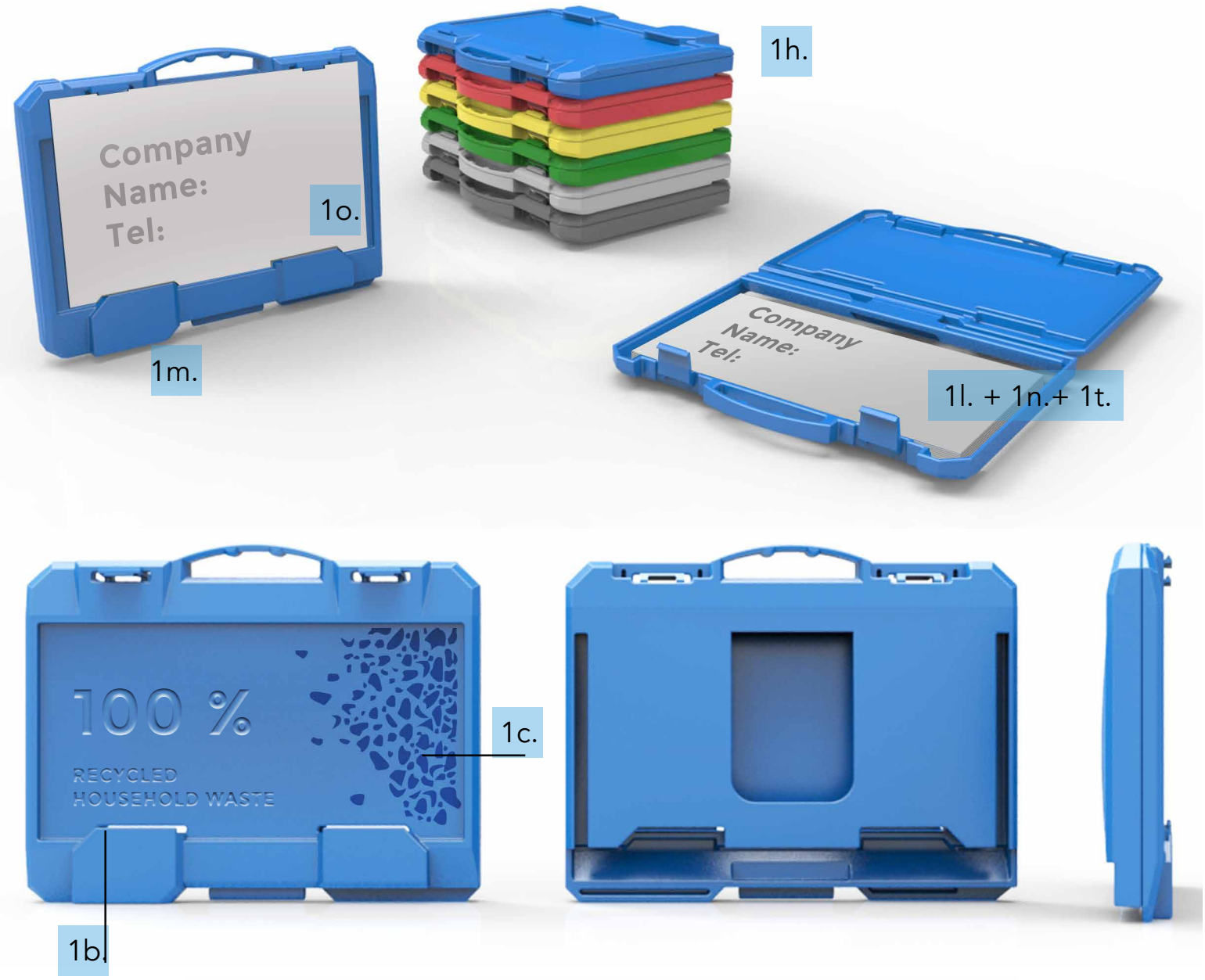
fig. 3.20 form fit on the lip at the back of the case

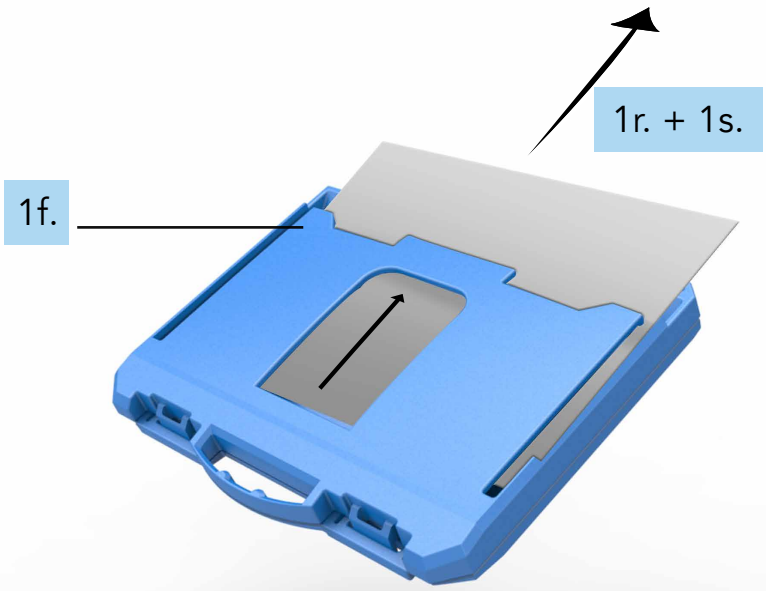
fig. 3.21 section view of stacked casees

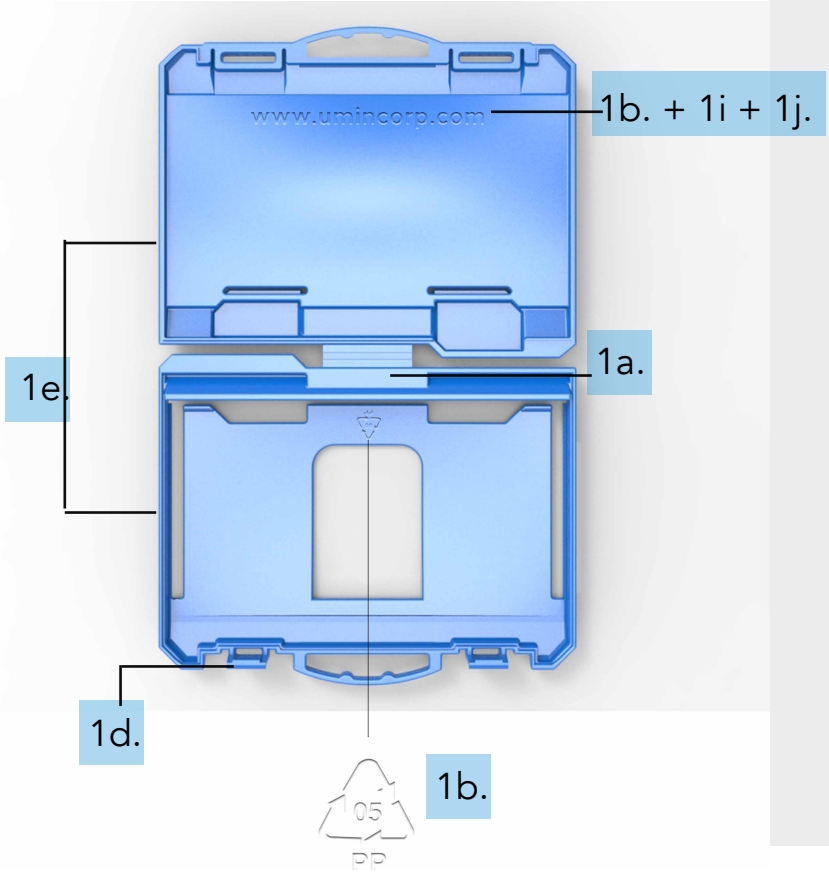


3.4 FINAL DESIGN

This chapter gives an overview of how the functions from the list of requirements are integrated into a final design. A proof of concept is conducted by testing with a 3d printed version of the cardholder.



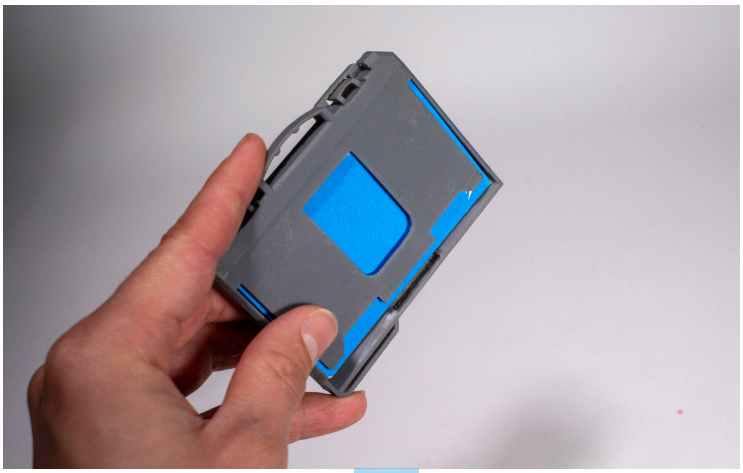




From: 3.3.1 list of requirements

1. FUNCTIONS
   - 1a. Living hinge
   - 1b. Embossed/debossed text/logo
   - 1c. Multiple surface finishes
   - 1d. Click connection/snap fit
   - 1e. Seal
   - 1f. Flexable function (not including snap fits)
   - 1g. Stackable
   - 1h. The product is produced in different colours.
   - 1i. The product gives a link to Umincorp's website.
   - 1j. The product gives information about the material price.
   - 1k. The product application should not interfere with current regulations about recycled plastic.
   - 1l. The product can store up to 15 business cards
   - 1m. The product can stand up horizontally by itself
   - 1n. Cards stored inside the product are protected from tearing or wrinkling
   - 1o. 1 card can be attached to the outside of the product
   - 1p. The product can be attached to a keychain
   - 1q. The product can be clipped horizontally and vertically to a pocket or piece of clothing
   - 1r. The product includes a dispenser function
   - 1s. No cards can fall out while using the product
   - 1t. Cards with sizes up to 91 x 60 mm can be stored inside the product

VERIFICATION WITH A 3D PRINTED MODEL

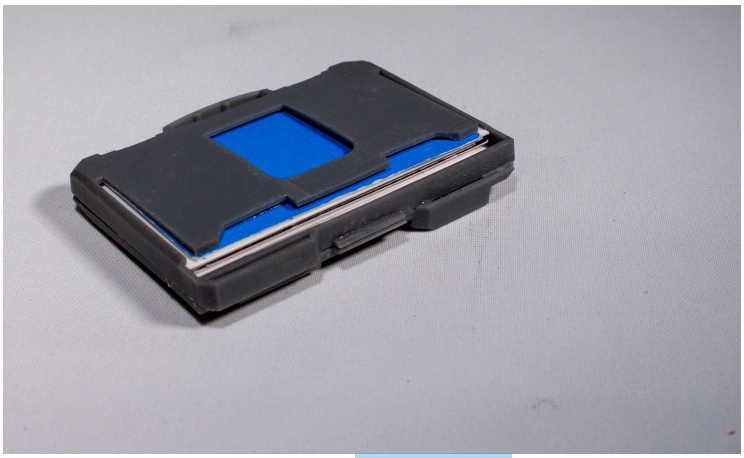


1s.

1m.

1o.

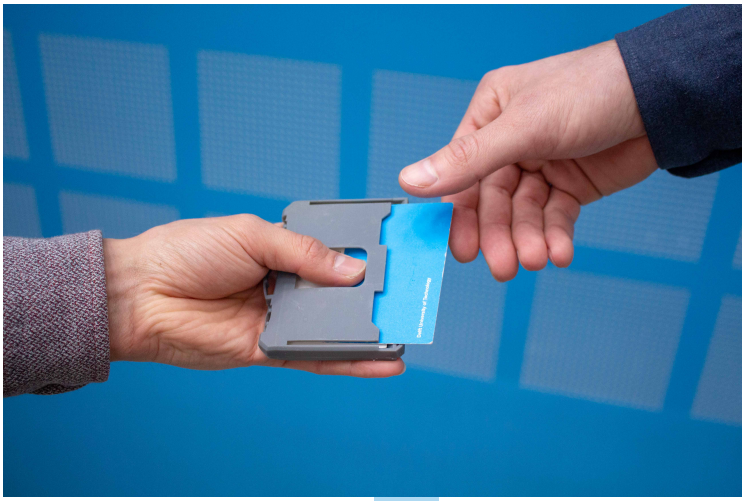
1g.



1l.& 1t.

1q.

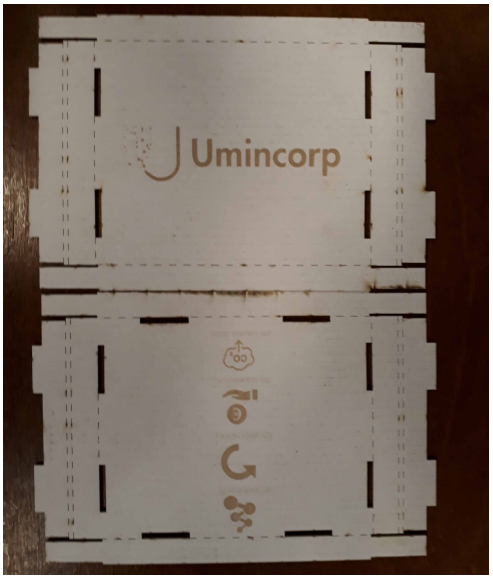
1p.

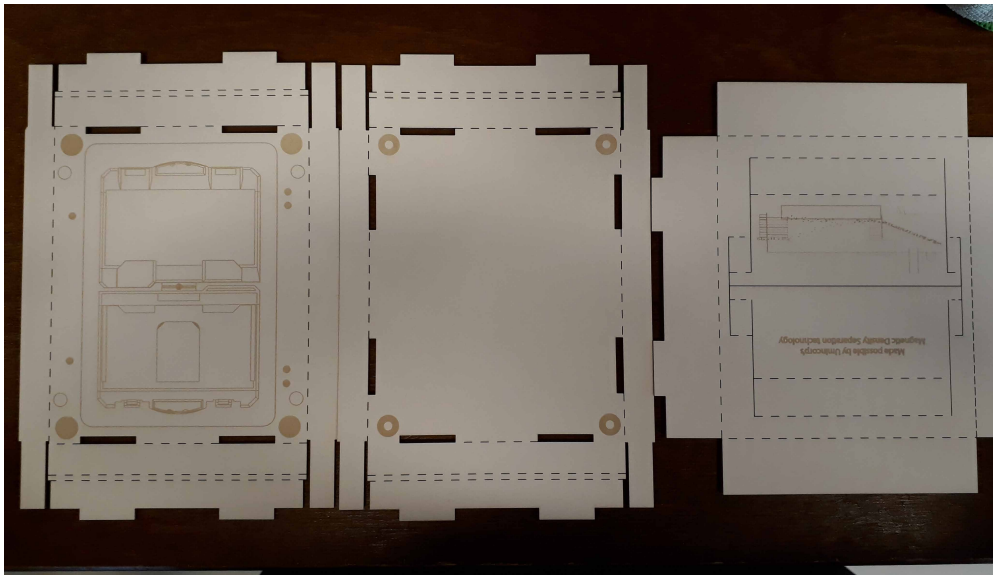


1r.

1j.

Additionally to the cardholder itself a cardboard packaging was developed to include some extra information about Umincorp and make a more complete business relationship gift out of it. The cardboard was cut and engraved using a laser cutter. The outside of the box was designed to resemble the mould of the product, by opening the two halves of the box, the product will become visable.





4.

PRODUCTION

This chapter starts off by showing the results of a colour separation process that was needed before delivering the material for production. The colour separated batches were delivered at injection mould producer P3d, for production in the 3d printed mould. Insights gained during the production will be used to come to conclusions and recommendations for the final chapter.

CONTENT

4.1 COLOUR SORTING

Umincorp is also working on the development of a high frequency colour sorter. The cardholders will be produced in different colours to show that recycled products don't have to end up grey or black if the right sorting technologies are applied. Umincorp's own colour sorter is still under development, but they do own an existing colour sorter that is designed to handle smaller batches of material. Next to colour sorting, this machine is also a flake purifier that can sort plastic types (see fig 4.1.). The first step was to clean up the 94% purity PP batch (see appendix 3) that will be used for production of the cardholders up to a 99+% purity. This was obtained by feeding the material into the machine two separate times.

Step 1	Purifying the material	Step 2
93.8% PP – 6.1% PE		98.4% PP – 1.6% PE
98.4% PP – 1.6% PE		99.1% PP – 0.9% PE
18.6 kg PP- 1 kg PE		18.4 kg PP – 0.2 Kg PE

The next steps consisted of feeding the material into the machines multiple times with the preferred output colour selected. The colour sorting option was not used by Umincorp before and asked for a lot of trial and error runs. In the end it was possible to see a clear colour change between the two outputs of the machine after two runs. However, it took many runs (+- 10) to obtain a more or less homogenous colour as can be seen in the batches of fig. 4.2

fig 4.2 Final output of the colour sorting test

For each colour between 0.5 and 1 kg of material was obtained. White flakes where the last to be separated and resulted in a final batch of about 2kg. With each run, material losses occur due to the imprecisions of the machines separation technology. White was the last colour to be separated and asked for less runs, thus resulted in less material loss.

This separation technology was sufficient to obtain small batches of material for the production of the cardholders. In practise a high frequency colour sorter will be needed for the processing of large amounts of plastic into homogenous separate colour batches. If less bright colours are acceptable for a given application, the current technology could already be applied to deliver semi homogenous colour batches. For future projects, colour tests could be conducted to find out if these batches already have a useful application.

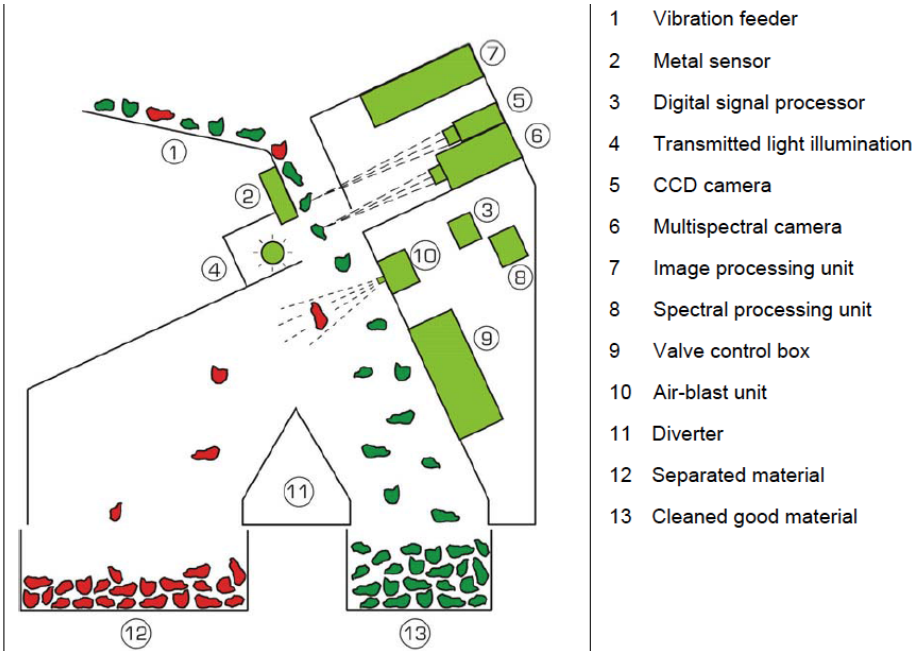


fig. 4.1 Schematic display of the flake purifier/colour sorter working principle

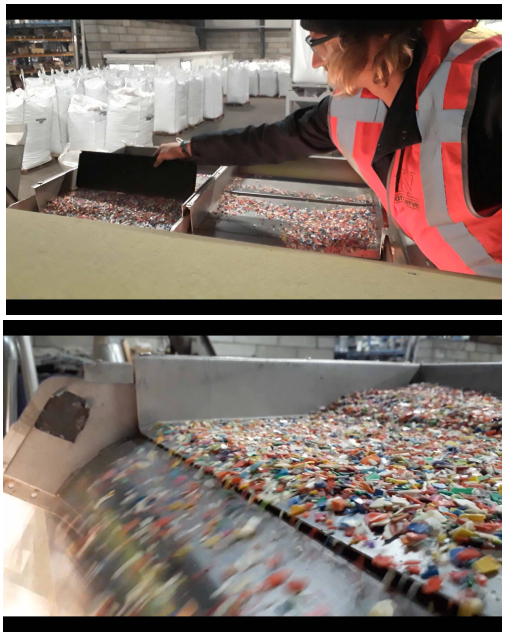


fig 4.3, 4.4 Manually feeding the material into the machine

4.2 PRODUCTION AT P3D

A 3d printed mould for the cardholders was developed and used for production by P3d. The colour sorted purified flakes (4-6 mm) were delivered together with a different batch of PP that was shredded into larger flakes (8-10 mm). The goal of the production was to obtain between 50-100 cardholders by using; virgin, red, blue, yellow, green, white, mixed 4-6 mm and mixed 8-10mm pp. Before the production started, a standard material test was conducted by P3d to get a first indication of the ability to process Umincorp's material.

4.2.1 RESULTS

The test shows that the injection mould machine has no problems in processing Umincorp's material. Some slight colour changes are visible, but these are due to the previous material that was used in this mould. Expectations from P3d were that a higher pressure would be needed for Umincorp's PP. It turned out that the required pressure to fill the test mould was more or less the same as for virgin PP.

An interview was conducted with P. Willems of P3d who was responsible for starting up the production.

- Do noticeable differences occur in settings like pressure and temperature compared to virgin PP?

''No noticeable differences occurred, the settings for pressure and temperature were more or less the same as would be expected when using a virgin PP''

- Do the settings need to be adjusted in between shots for separate products?

''We adjust the settings until the mould fills correctly. Once this is done we leave the settings as is. No adjustments in between shots were necessary. ''

- Are there certain problems that you come across during production while processing Umincorp's material?

''The batch with the bigger flakes started to block the screw of the injection mould machine after a few shots. The other batches including the smaller flakes were not a problem. If they are the right size, delivering these flakes instead of granules is not a problem for our production

fig 4.5 material test speciment produced with Umincorp's PP

fig 4.6, 4,7 Mould installed in the injection mould machine

process. Nevertheless, the smell that occurs during production is a turn off.''

- What is your first impression of the material and do your expectations meet the end result?

'The results are better than I expected after just looking at the material. The batch with the larger flakes had more contaminants and results in burned spots or accumulation in smaller parts like the hinge. This is something that can be expected.''

- What influence does the 3d printed mould have on the product compared to a regular mould?

''While producing with a 3d printed mould you have to be more careful when applying pressure. The moulds are sensitive and parts can break off. This thin walled product needed more pressure than expected. So instead of 50-100 products, we were only able to produce 14 products before the mould broke. Furthermore, our machine only has 25 tons of closing power. This was expected to be enough, however you can see that a lot of flashing has occurred on the edges of the product. More closing force will be needed to prevent this, because of the large surface of the card holder.''

- Which improvements could be made in order to achieve a better end result?

'' As many contaminants as possible should be cleaned from the material, for the colour sorted batches this is already really good. A better end result depends more on the type of mould we used than of the material's quality. The design of the cardholder is reaching the limits of what is possible within a 3d printed mould. Furthermore, the hinges show a lot of whitening, I am not sure if this is due to the material's properties. Deviation from the standard dimensions for a living hinge might improve this.''

fig 4.8 3d printed mould for the cardholders

fig 4.9 Cardholders that made it through production. The product on the front is the result that occured during the failure of the mould.

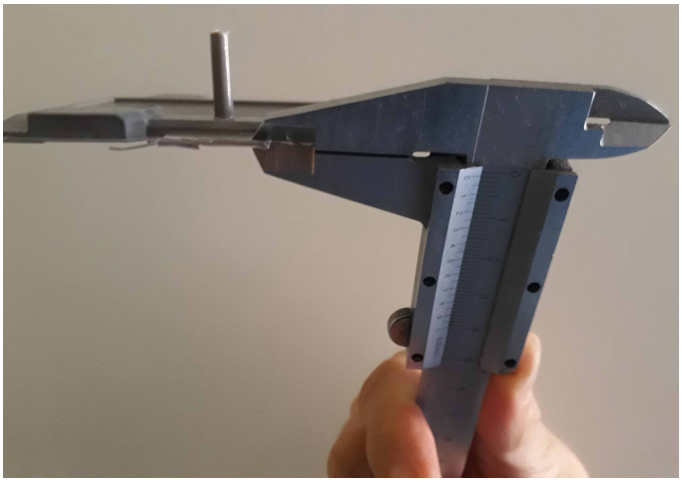


fig 4.10 Evaluation of the living hinge

4.2.2 EVALUATION

Measurement of the living hinge shows that the dimensions are not the same as in the cad design. The middle part that shows the whitening is supposed to be 0.3 mm thick, in the produced product this is found to be 0.6 mm. This part usually lies between 0.254-0.635 mm (Protolabs, 2018). There is still a working living hinge in the produced products, but it is reaching its limits in thickness. Another reason for the whitening could be that the material is more brittle due to the shortening of molecular chains or a high amount of fillers in the material input.

Besides the thicker living hinge, more deformation can be found in the product. This is clearly visible in the closing line of the product. Tolerances for the 3d printed mould are due to the production method and the material not as precise as in a steel mould. The cooling process was conducted by leaving the mould closed for a relatively long time. Common used cooling methods have integrated cooling systems in the mould. More control over possible deformation can be obtained by this.

Although the surface finish of the products exceeds the expectations of the material, some minor colour differences can still be spotted. In a few products some minor burn spots can also be found, these are due to the difference in melt temperature of the tiny amount of impurities that are still present in the 99+% purity material. A more homogenous colour could be obtained by using a higher pressure during production, optimise mixing of the material by the machine or simply using granules instead of flakes.

Finally some last improvements on the design can be;

- Increasing the thickness of the keychain attachment on the top part of the product.
- Creating a more user friendly clickfinger design.
- Refining the tolerances in the dimensions of the product.

fig 4.11 The inisde of a finished cardholder

fig 4.12 The outside of a finished cardholder

fig 4.13 Finished cardholders stacked together

fig 4.14 All the finished products that will be exhibited at Umincorp's stand at the Plastic Recycling Show in the Rai in Amsterdam the 10th and 11th of April 2019. From left to right: Keychains produced at Mafa, Rotomoulding powder produced by Zweva, Colour sorted PP batches used for production, cardholders in 5 different colours, test piece for injection moulding, Ihorns with a virgin example in purple.

Unfortunately P3d made the mistake of not using the most recent file that was send to them for production. The iteration to the clickfingers (see chapter 3.3.2) was not included in the mould. After applying pressure on the mould for the first product, the cores of the click fingers broke resulting in unusable click fingers. The alteration in the most recent file should have prevented this from happening. Due to a communication error with P3d, the texts and logo's were also not included in the mould. Furthermore, the delivery time of the finished cardholders was also postponed by 3 weeks. A negotiation with P3d could be made about how to move forward. This will be summarised in the recommendations of CHAPTER.

Conclusion part 1/2 D.A. 6 PRODUCTION

How does Umincorp gain insight from the realisation of this product?

Positive insights are; that except for the smell, the material's qualities did not obstruct the process of production. Recycled flakes shredded to 4-6 mm can be processed without any problems. Surface quality of the products and the colour give a good first impression of aesthetic qualities that the material can obtain. The settings on the machine also didn't deviate from the norm and show that the recycled PP is able to fill the mould accordingly to virgin PP. Expectations from the producer about the ability to process the material were positively overruled.

The results of the cardholder show that a relatively complex product with many injection mould features is difficult to realize in a 3d printed mould. The amount of pressure needed for this thin walled product with its large surface area turned out to be more than was expected by P3d. Only 14 products could be completed because of this. With this amount the product can still act as a showcase for Umincorp, but it will not be enough to give away to business relations. Next to this, no virgin versions where produced, because the mould failed earlier than expected.

Umincorp would still like to see a finished product next to the insights that this first production delivered. Findings from the interviews in the following chapter are used to help find an efficient way to move forward.

5.

CONCLUSIONS

This chapter starts off with 4 final interviews that were conducted with developers of injection mould products. These interviews act as a discussion for the results of the final product and will be used to come to conclusions and recommendations for Umincorp. This can act as a starting point for Umincorp if they decide to work on the development of more products. An evaluation of the project can be found at the end.

CONTENT

5.1 VALIDATION

According to the assignment, an answer should be found to the following question:

Does the cardholder help to convince the target group that Umincorp's material can be used as a valuable resource?

4* Interviews where conducted with test subjects from the target group to gain insight in this question. The production of the cardholder was not completely finished during the interviews. To gain enough information, the keychains from the tests at Mafa where used as a material reference. The structure of the interviews was as follows:

1. What experience does (company name) have with recycled plastics?

   .. Introducing Umincorp and their business.
   .. Showing the recycled flakes to the test subject.
   .. Handing out the keychains to the test subject.

2. What do the keychains tell you about the quality of the material?
3. How do your expectations about the material meet the results of the keychains?

   .. Handing out the 3d printed cardholder to the test subject.

4. How can the cardholder help to convince you of the material's qualities?
5. How would you use the cardholder if it were given to you?

   .. Handing out the lists of positive and negative emotions to the test subject.

6. Which of the following emotions can you relate to after seeing the keychains and cardholder?

The user experience test, information about the companies and summarized transcripts can be found in appendix 11.

fig 5.1 Interview material

INTERVIEW T. SCHUUR, SENIOR DESIGN ENGINEER AT:

VANBERLO

According to T. Schuur Van Berlo does not have much experience with recycled plastics for product design. They would like to do more projects with recycled plastics, however uncertainty about the material quality and the perception of the user have led to little development on this topic. Van Berlo is able to make suggestions for material usage, but in the end the customer decides. There was one recent project where recycled plastics were used. This was a bulky part that was used outside, was not visible and was a cheaper option than the previous material that was used.

'' The keychains look neatly finished; I don't see any weird things happening. I would say that the quality of the material is good, but I would ask for a different colour. This colour looks a bit like a dull colour from the 70's.''

'' I think it's important that we tell a customer a certain material is possible and ok to utilize. A product like the business card holder is a useful and easy way to make this clear to a customer. If you would compare a virgin version to a recycled version with similar quality for a lower price, it will be a no-brainer for customers to decided which one they want.''

'' I'm impressed by this result, why shouldn't we use this more often?''

+ Hope
+ Inspiration
+ Pleasant surprise

- Doubt

INTERVIEW S. HOEKSTRA, FUNCTIONALY DESIGNER & T. DRIESSEN, SENIOR PRODUCABILITY DESIGNER AT:

ACHIEVING VALUE TOGETHER

MMID

S. Hoekstra is part of the sustainability team and the foundation projects that are running within MMID. The foundation team supports external sustainable projects and is also linked to a few products about plastic recycling.
MMID mostly works for customers and recycled plastic is not used very often. The costumers decide which material is used for the product and they need to be convinced there will be limited risks when using a material like recycled plastic. Convincing them is a difficult task.

'' Customers don't want to be afraid to have a chance that 30.000 faulty products end up on the market. All the risks need to be taken care off, so the choice for a material will be water tight''

''At the beginning of a project there are often goals about sustainability. This usually asks for extra development time. Projects are often money driven. When time is running short and budget is tight, these goals are usually the first to be let down.''

'' The key for sustainable design is the ability to make money out of it, this is often the hurdle''

''The keychain says very little to me. The colour is funny and the injection mould quality is pretty good, but it doesn't tell me a lot for my own applications. If the recycled hinge would hold as long as the virgin hinge I would be very surprised''

''I wouldn't use this product as a business card holder myself, but it would end up in the material library of MMID so it can be used as a reference''

''As an engineer, proper datasheets composed by an external party would convince me. If your sheet says it has 90% of the strength of virgin I would think; seriously!? I want to try it myself. If you would dare to give me a test fixture I would be very impressed''

+ Excitement
+ Fascination
+ Hope
+ Inspiration
+ Pleasant surprise
- Doubt
- Insecurity

INTERVIEW P. VAN 'T VEER, DIRECTOR AT:

ZWEVA ENGINEERING

Zweva engineering is a company focused on the development of rotation mould products. van 't Veer is also experienced in the development of injection mould products and was asked to partake in an interview. At Zweva they recently gained some experience in developing a rotation mould product with recycled plastics from household waste. According to van 't Veer the qualitative performance of the material shows opportunities, however the investments to process the material make it a challenge to make an economical viable business out of it.

''I like the taupe colour and the homogeneity of the material looks really good.''

'' I wouldn't expect such a consistent colour. If you didn't tell me, I would expect to see 3 virgin materials; a nice carbon black, a transparent one and a taupe one.''

'' The business card holder is a nice way to see product related properties in practise. Impact strength or tensile strength is difficult to test properly with this product because you don't have a reference. However, I do like practical tests and as a first test I would for example throw it on the ground or try to bend it. This can already be a useful first test before deciding if further material research is necessary.''

'' To me a printed mould does give a flawed image of how the material will behave in a real mould''

''When you attend a business fair as a company you need to have a gadget. Choosing a specific gadget that people will actually use is a difficult task that we also come across at Zweva. To be honest I wouldn't use this product as a business card holder, but I wouldn't throw it away either. It is a nice little product with some critical parts in it that I can show to customers. In my experience a lot of injection mould producers have all these parts lying around that you don't know the function of. An understandable product like the business card holder is more appealing.''

+ Elevation
+ Hope
+ Challenge
+ Inspiration
- Doubt
- Insecurity

INTERVIEW T. FEENSTRA, PROJECT LEAD AT:

PEZY GROUP innovation accelerators

T. Feenstra is a project leader at Pezy and has a personal interest in sustainable product design. In 2009 Pezy started focussing on cradle to cradle development from a sense of responsibility.

''Sustainability used to be a requirement that was easily lost by customers during product development. The urgency of sustainable development is becoming more generally known and I do notice an increasing need from customers for these kinds of projects. I am curious and optimistic about the developments for the coming years.''

'' There is less aesthetic freedom when you compare the recycled keychains to the transparent virgin version''

'' We wouldn't buy flakes to use with our machines. The recycled materials we use are always compounded into granules first. For rougher products like pallets I would expect it to be ok to use flakes directly. I am curious how the material will behave for smaller more detailed products, we haven never tried it. Unknown is unloved''

'' The possibilities of the material are completely dependent on the type of product that you want to make with it. The material seems suited for this keychain application, but if I want to design the case for lets say a coffee machine, it does not tell me this''

''The cardholder gives me a certain amount of information and next to this it's a nice gadget. It is a good way to give information about aesthetic properties and surface quality. It does not give me much information about mechanical properties. I would also like to try the material myself and receive datasheets, before I would be convinced of the material's qualities.''

+ Fascination	- Danger,
+ Compassion	- Disappointment
+ Tenderness	- Insecurity

*5 interviews would be a proper amount when conducting a usibility test (N.N. Group, 2000). The setup and scale of this interview was verified by Agnes Tan of the product evaluation lab at TU Delft. After 4 interviews a clear conclusion already formed and it was decided to drop the final interview and use the limited time that was left to focus on the problems that occured during production.

fig 5.2 .... they like to try and break stuff.

Conclusion part 2/2 D.A. 6 PRODUCTION

The cardholder and keychains seem to convince the target group up to a certain level. Aesthetic properties like the homogenous colour and surface quality obtained by using the flakes directly for the injection moulding process is something that appears to surprise people.

Two of the interviewees asked if the could keep the keychains and receive a cardholder once they are finished. They were interested to show a nice understandable product to clients, keep it in the company's material library or compare it to a virgin version. It sounds like people who will receive it are more likely to use it in such a way that it acts as a conversation starter and reference for their clients when discussing possibilities for recycled plastics. For them the product properties could also be translated in a different kind of product. The cardholder function itself is more relevant for employees of Umincorp during a business fair.

Although the product can give some first impressions about mechanical properties, it does not give any hard data. To really convince the target group about the material's value, these datasheets should be available and complete. A clear image should be created about the mechanical properties of Umincorp's material. The changing input of household waste plastic makes this a challenge. Regularly updated datasheets composed by an external party would be a reliable way to make this information available.

So the cardholder seems to be able to breach some first preconceptions about the quality of recycled plastics from household waste. This is helpful to open up the conversation about possibilities for utilizing this material. It shows some qualitative and aesthetic qualities, but it does not give all the information people need for their own applications. For some, this can already be a trigger to try and experiment with the material. However, to really convince designers or producers to use it, more of their insecurities need to be taken away. Transparent quantitative information should be available in a similar way as virgin plastics offer this to gain more trust and make Umincorp's material more accessible to work with.

The recommendations in the next chapter will go into the steps that Umincorp can take for further development of the product from the assignment.

5.2 RECOMMENDATIONS

Now that there is a design of a product and the first production tests, Umincorp will have to decide on how to move forward. The first production at P3d shows that another mould will have to be made in order to get the finished cardholder. With the updated mould a working product should be possible to obtain. However, it also became clear during production that the geometry of the cardholder makes it a challenging product to produce in a 3d printed mould. Only 14 complete products were produced before the mould broke. This is will not be solved by the updated mould. Umincorp is in a position were they could demand a new mould, because of the delay and the mistake by P3d to use an older file. P3d proposed to give a discount and do some manual work on the finished cardholders, so there would still be an end result that can be used as a showcase product. Next to this, they are willing to produce a small batch of Ihorns (see FIG.) in virgin and recycled material in one of their own moulds.

Pointing out the insights gained during production, the final interviews and the fact that P3d has also helped by allowing different colour batches of recycled material to be used during production, it will be recommended not to focus on the development of another 3d printed mould. Producing existing products with Umincorp's material together with other companies would be a more efficient way to convince potential customers about the material's value. This has been tried earlier in this project and showed to be difficult without any product examples. Now that Umincorp has the keychains, cardholder tests and Ihorns, they have a stronger position to try this again. First preconceptions about recycled plastics like surface quality and processing abilities can be breached by these kinds of examples and can help to convince companies to try it out in one of their existing moulds. This approach could help Umincorp to obtain different completed product examples produced with their material and more contacts in product development.

Next to qualitative information in the form of showcase products, Umincorp should also focus on giving more insight in quantitative information of their material. This will help producers and designers to get more direct information for their own applications. It also a way to gain trust by presenting Umincorp's material in a more similar way like virgin plastics. The following concept is a final recommendation of a follow up project for this assignment.

A sample case put together with sourced parts produced with Umincorp's material.

The case includes:

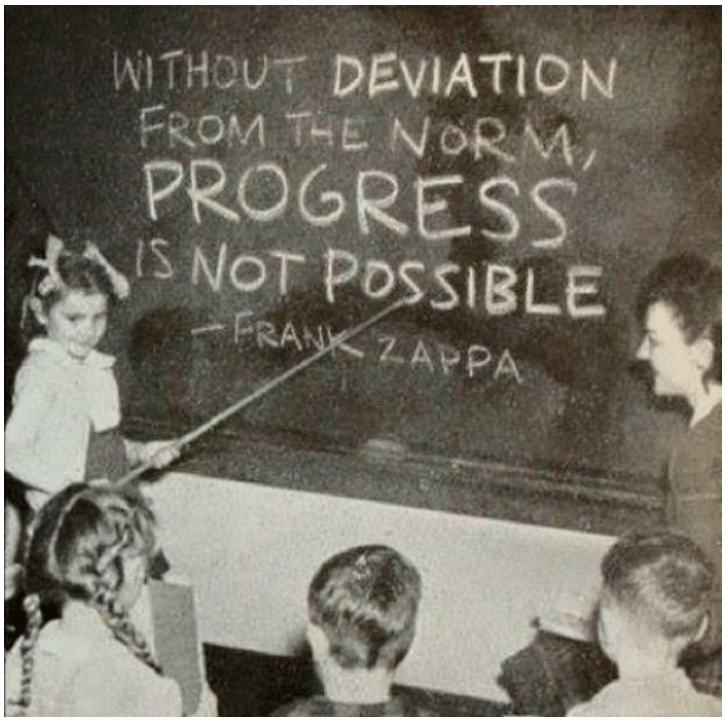
- ASTM tensile test specimens
- Charpy impact test specimens
- flexibility samples
- textures sample

5.3 EVALUATION

The assignment for this project started off with a very broad scope. Possibilities to process Umincorp's material needed to be researched and defining a specific target group was complicated. To conduct material tests and try the material out in practise, external companies needed to be included. Injection moulding was tested out early on in the project and already gave an interesting result. A conclusion to focus on this production process was made much later. Other production methods were looked into to find more possibilities. This took time and resulted in confusion of in which direction the project was going.

A more clear direction started to develop when the possibility of a 3d printed mould came to light. This gave the opportunity to develop a whole product suited for mass production and prototype it for relatively low costs. It was also a way for Umincorp to receive insights in the development and production process for a product by following it up close. The goal of this production was also to get a finished product. This unfortunately did not succeed due to the inconveniencies that arose during production. Developing and producing a product for injection moulding is a big task and setbacks can be expected during this process. Enough investments in time and costs should be taken into account for this. To get a finished product for Umincorp this was probably not the most efficient approach. It did result in knowledge and some first examples that Umincorp can use to move forward.

The conclusions and recommendations of this project point to a more transparent way of presenting recycled plastic similar to virgin plastics by making the material more accessible in a known fashion. I think this will be a rational way to move forward for Umincorp. From a more idealistic point of view, I believe that designers should also take their own responsibilities. Although quality of recycled plastics is improving, they are not the same as virgin plastics. Deviations from the norm should be accepted as a part of the design process when material options like recycled plastics or even renewable natural materials are considered.



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