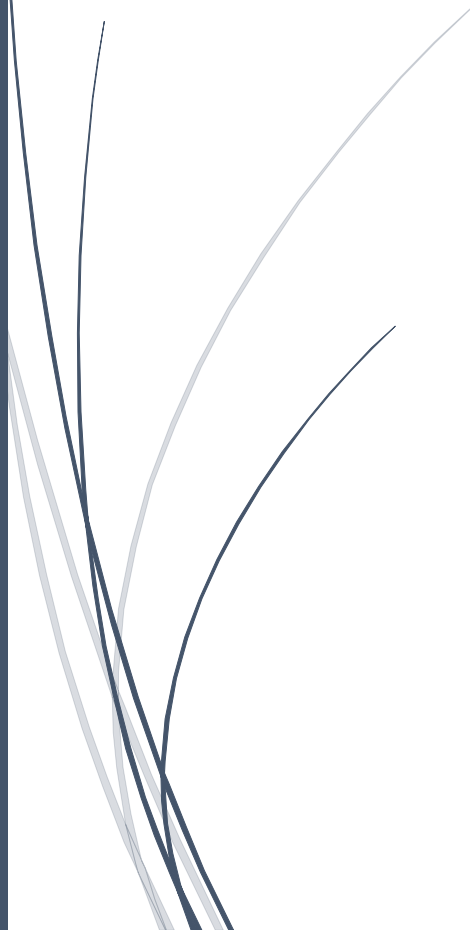




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Materials & Introduction to Manufacturing

Polymer Moulded Bottle Assembly



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1. Executive Summary

This report highlights the material selection process and explains how materials are selected and gives a brief outline of the costs of each material. The report then explains the manufacturing process and the importance of the mould cavity being created. The different manufacturing processes are then explained and the reasons why they are and are not used. The production process is then explained along with the health and safety concerns towards any customers who consume beverages from the manufactured bottles and the risks involved in reusing plastic bottles.

2. Introduction

This report will aim to explain the methods in which plastic water bottles are manufactured and mass produced. The report will be broken down into different sections, explaining the materials that are used for the manufacturing process along with the reasons why. The different stages of manufacturing the product will then be discussed, along with the production methods and any health and safety concerns that are related to bottle manufacture.

3. Material Selection

According to (Open University, 2016) the first stage of mass producing a product is the material selection. There are certain properties that a plastic bottle must have for it to fulfil its purpose and satisfy the customer's needs. The selection of the appropriate polymer to use is a critical stage of the design exercise, meaning it requires several stages of different techniques. This is due to fact that the material choice is important as it helps determine the best outcome for the finished product. To ensure the best final outcome for a product, companies must compare the different characteristics and properties between a range of materials. Companies will likely compare different statistics regarding the tensile strength, melting points, impact resistance and cost.

3.1 Materials

The material used to manufacture plastic bottles is generally polyethylene terephthalate. This material can be either amorphous or up to 30% crystallised according to (Groover, 2010). The materials ability to cool quickly favours the highly transparent amorphous state, making it ideal for plastic containers. Figure 1.0, shows the characteristics of this material, which may explain the reasoning for why so many beverage companies use this material for their product packaging. Polycarbonate (shown in Figure 1.1) is also used for the manufacture of plastic bottles. These materials are used for the manufacture of this type of product due to how they are strong but lightweight.

TABLE 8.3 (continued): (h) polyesters (thermoplastic).			
Representative polymer:	Polyethylene terephthalate ($C_2H_4-C_8H_4O_4$) _n		
Symbol:	PET	Elongation:	200%
Polymerization method:	Step (condensation)	Specific gravity:	1.3
Degree of crystallinity:	Amorphous to 30% crystalline	Glass transition temperature:	70°C (158°F)
Modulus of elasticity:	2300 MPa (333,590 lb/in ²)	Melting temperature:	265°C (509°F)
Tensile strength:	55 MPa (7975 lb/in ²)	Approximate market share:	About 2%

Figure 3.1.0 shows a characteristic table for polyethylene terephthalate (Groover, 2010).

TABLE 8.3 (continued): (g) polycarbonate.			
Polymer:	Polycarbonate ($C_3H_6(C_6H_4)_2CO_3$) _n		
Symbol:	PC	Elongation:	110%
Polymerization method:	Step (condensation)	Specific gravity:	1.2
Degree of crystallinity:	Amorphous	Glass transition temperature:	150°C (302°F)
Modulus of elasticity:	2500 MPa (362,590 lb/in ²)	Melting temperature:	230°C (446°F)
Tensile strength:	65 MPa (9425 lb/in ²)	Approximate market share:	Less than 1%

Figure 3.1.1 shows a characteristic table for polycarbonate (Groover, 2010).

Despite the similarities, PET is used more for this line of manufacturing. This could be to do with its higher elongation value, making it more suitable for a blow moulding manufacturing process. This material is also suitable due to how it is non-reactive, making it safe for the consumer to eat or drink any products stored in a PET bottle. This material is also 100% recyclable and impact resistant. (PETRA, 2015).

3.2 Cost

The material trading site (Alibaba, 2018) can compare the costs of raw materials that are to be purchased by companies, so that they have an idea of how much they will have to spend, depending on the material they select. The site lists PC at \$2600-\$2900 (£1800 - £2100) per tonne of material and PET at a much cheaper \$635-\$1350 (£460 - £970) per tonne of material. This is a vital stage when it comes to production as the UK consumed approximately 3.6 billion litres of bottled water (including water coolers) according to (BBW, 2016)

For a company like Princes Gate, who sold approximately 60 million bottles of water in 2013 (Approx. 1.7% of the bottled water sold in the UK), keeping material costs low is a huge factor to achieving success. Manufacturing water bottles out of PET will save the company thousands in material costs as it works out as less than half the cost of PC.

One of the main ways to control the costs and increase profits for companies is to focus on the packaging. (MJS, 2017) states that packaging costs make up around 70% of the total cost of producing plastic bottles. The appropriate manufacturing process will be taken by companies to ensure that not much money is wasted on unnecessary packaging.

4. Manufacturing Process

To achieve identical bottles in the huge quantities that are required by drinks companies, the selection of the correct manufacturing process is key. This process must be consistent and cheap if a company aims to mass produce and keep profits high. In order to do this, a mould must be created in order to achieve the same shaped bottle over and over. There are several methods of doing this which may include CNC machining and 3D printing.

4.1 Creating the Mould

3D printing the mould will ensure a very accurate result and only takes several hours to build. This part will also be completed by the printer, eliminating the need for manual labour. 3D printing also benefits as it does not cost a huge amount of money to produce the mould and does not take a long period of time to produce the mould either. This means that the design can be verified by the printer before mass production to ensure the ergonomics and fit of the product are appropriate. 3D printed prototypes are also ideal as tests can be carried out to measure strength and corrosion limits (Innovation, 2015).

Due to the high thermal expansion coefficients in polymers, when the part cools it is likely that it will be affected by shrinkage. This occurs when the plastic starts to cool drastically from the moulding temperature to room temperature. To ensure that shrinkage does not affect the final product, moulds should be made slightly larger than the part needs to be to accommodate for any shrinking material. Polyethylene shrinks by 0.025mm when fully cooled, making it one of highest shrinking thermoplastics. Weld lines, flash, voids and warping can occur during the injection moulding process. Any parts affected by any of these would have to be scrapped (Groover, 2010).

While the mould itself is not cheap to make, once it has been made it can produce thousands of parts making it well worth the investment.

4.2 Blow Moulding

According to (Groover, 2010) this process is derived from glass blowing. The difference being, instead of glass, this process uses molten plastic. This process is accomplished in two steps. The first step is to create a parison. This parison is made by fabricating a tube of molten plastic. The second step involves the use of pressurised air to inflate this parison, filling a mould cavity with the soft plastic which will then take the shape of the mould once cooled. There are two methods of creating the parison, injection and extrusion moulding. The process used in creating the parison will determine what type of plastic bottle will be produced via that method.

4.3 Extrusion Blow Moulding

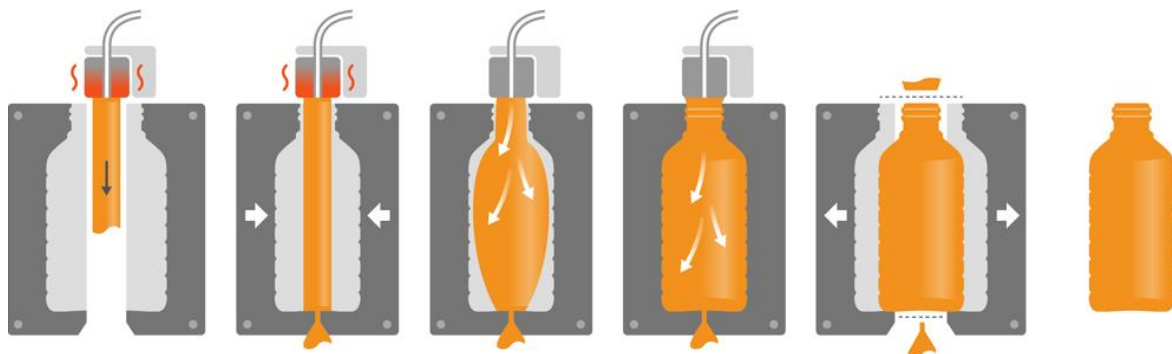


Figure 4.3.0 shows extrusion blow moulding step by step.

In this type of process, the plastic is melted down into a hollow tube, creating the parison. The mould then closes around the parison, clamping it into place. The parison is then inflated with the use of compressed air, enough so it fills the mould completely. Any leftover material is then trimmed from the top and bottom of the mould and the finished product can then move on to the next stage of the production procedure. This type of process accumulates a lot of waste due to the offcuts that are taken from the top and bottom of every bottle that is made. However, these offcuts can be melted down and reused in some cases.

4.4 Injection Blow Moulding

This process injection moulds the parison into the mould that was designed in the previous stage of the process. The parison is then inflated with compressed air which inflates it, filling the mould. When the plastic cools and sets, the mould is removed to give the final product ready for the next stage of production, leaving no waste material. As well as not wasting any material, this process also gives an accurate finish consistently, providing the mould is in good working condition. (Groover, 2010).

Another benefit of this type of manufacturing process is that it can accommodate to a variety of bottle shapes. Due to the 3D printed injection mould, this process can produce bottles of different shapes and styles, unlike extrusion blow moulding which can only produce bottles of uniform thickness.

4.5 Injection Stretch Blow Moulding

This manufacturing process is a variation of injection moulding (See part 4.1 of report). This process is fairly similar to injection blow moulding but has one main difference. Instead of being inflated with pressurised air from the neck of the mould, the blowing rod is fed into the injection moulded preform, stretching it in the process. The preform then inflates the mould simultaneously, ensuring that the air pressure is shared throughout the plastic and does not apply too much stress on specific areas. Stretching out and blowing air from the middle of the mould first creates a more favourable stressing for the polymer resulting in a more rigid structure that is also more resistant to impact, making it ideal for bottled beverages. The material that is most commonly used for this type of manufacturing process is polyethylene terephthalate (PET), see section 3.1 of report. This type of material suits the process and the initial inflation strengthens the polymer.

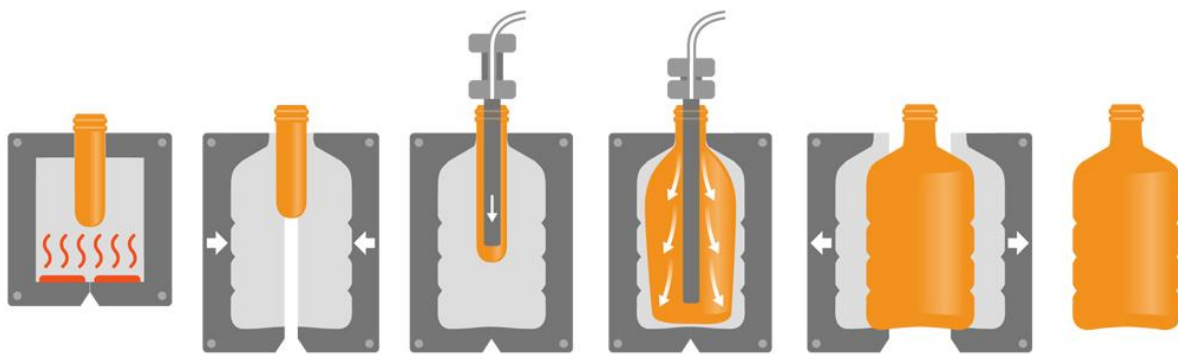


Figure 4.5.01 shows the step by step process of injection stretch blow moulding

5. Environmental

One of the main reasons behind PET plastic being used for such a large percentage of plastic bottle production is that it is recyclable. This type of polymer can be recycled more than once, over and over again. When PET is recovered from recycling plants, with the help of various washing and chemical induced processes, the used plastic can be broken down and purified. This newly purified polymer can then be converted into PET resin and used again and again, providing that it is recycled again (PETRA, 2015).

According to a survey carried out by (BFP, 2018), almost 60% of PET plastic bottles that were thrown out as household waste were recovered and recycled. This figure is up a huge 57% from 3% in 2001. It is vital that this plastic is recycled as it is non-biodegradable, meaning that it will not decompose and avoid pollution as it is a plastic.

6. Production

The mass production rate of plastic bottles will depend on the manufacturing process that is being used. Plastic drinks bottles are often produced via injection stretch blow moulding, which can use a two stage process method that will increase production rates. However, the two stage process does have its drawbacks. It is not a very efficient process as the machines waste a lot of energy as they give off heat. PET plastic particularly favours this process with approximately 80% of all PET bottles being produced by the two stage method (CYPET, 2018).

Despite injection blow moulding using less energy and resources due to its single stage process, the single machines cannot compete with the two stage machines when it comes to the output quantities. Other types of bottles which do not require the volumes that beverage bottles require may use the more efficient method of injection blow moulding. Due to the 3.6 billion litres of bottled water that is purchased throughout the UK, the production rate of bottles is the main priority. (BBW, 2016)

7. Health and Safety

The main concern in regards to the customer when it comes to plastic bottles is the leaking of any chemicals from the plastic into the bottles contents. This is especially a concern for manufacturers of water bottles and other liquid beverages. The chemical BPA can be found in 'Type 7' plastic bottles and is linked with health problems in pregnant women which could potentially lead to birth defects. PET plastic bottles are marked as 'Type 1' bottles, containing no BPA chemicals. This highlights why the material selection process is essential when manufacturing plastic water bottles. However, bacteria is still a concern with this type of plastic as some bottles may be difficult to clean, according to (Live Strong, 2017). For this reason, manufacturers do not promote the reuse of their plastic bottles and will always encourage the customers to recycle them.

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