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BA Product Design

Materials and Manufacturing

ADDA4001

Assessment 2

Component Analysis——Metal Tap / Faucet

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A faucet is a valve that controls the flow of water. It is usually made up of these parts: spout, handle(s), lift rod, cartridge, aerator, mixing chamber, and water inlets. (How products are made, 2019) The majority of residential faucets are single or dual-control cartridge faucets. The faucet of an English lavatory basin or bathtub is usually cold and hot separated at both ends. In the United States and other countries, most of them are mixed faucets. The latter only comes out of the water after it is mixed with cold and hot water, so it can be controlled at different temperatures to use water.

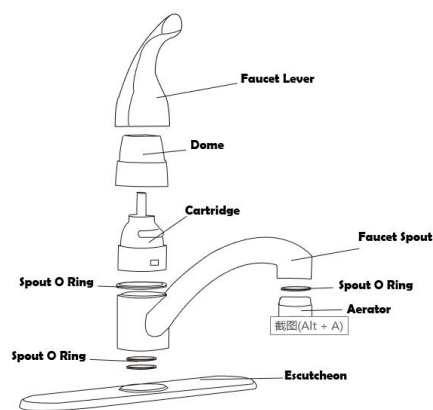


Figure1

In this report, I will be looking into the raw materials, manufacturing processes, costs, production scale and so on about metal tap. In addition to , I will provide an alternative material choice, manufacturing processes for it. My report will focus on single-control cartridge metal tap. (As shown in the following picture)



Figure2 (From:Blanco)

Materials:

Any material that will hold water can be used to make a faucet. Therefore, they can be made from glass, ceramics, wood and other materials, although these are not very common. Usually, the faucets are made of metal, such as copper, brass, bronze, alloy zinc, stainless steel, etc., and, of course, plastic can also be made into faucets. Different materials will have different characteristics. (Starcraft Custom Builders, 2018)

The most commonly material for making faucets is brass. Brass is an alloy of copper and zinc, known as yellow and yellow. (Wikipedia) Its mechanical properties and wear resistance, corrosion resistance, so it has become the first choice of faucet materials. And its melting point is low, indicating that it is easier to cast. In addition, it is soft enough to be machined. Another thing I have to say is that it's easy to recycle, and about 80% of the brass on a new faucet can be made something else. (Encyclopaedia britannica)

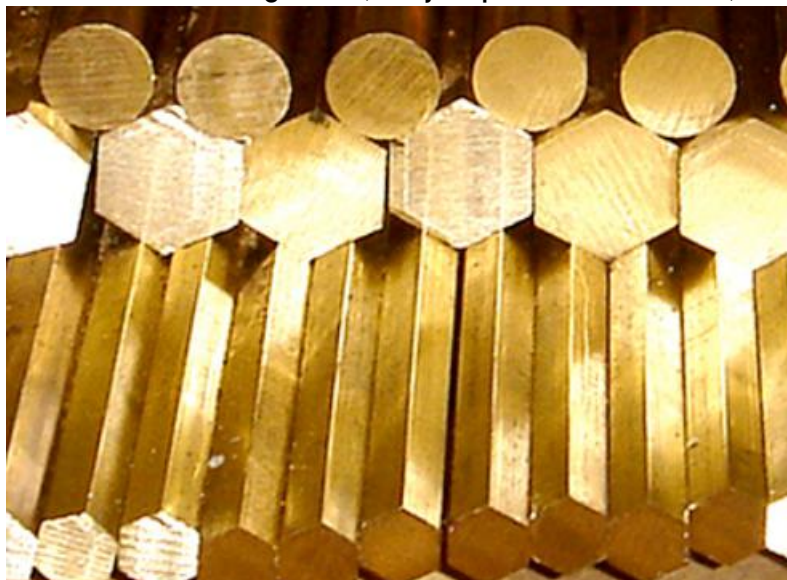


Figure3 (From: Tech Leong)

Other materials, by contrast, are less satisfactory. For example, cast iron is easy to rust and stainless steel is hard and difficult to process. Also Poor stability of zinc alloy, causing tap to burst easily.

Brass is divided into many types according to the content of copper. At present, most faucets use H59 copper, that is, brass, which accounts for 57% to 61% of copper. In fact, some international bathroom brands will even use H62 copper to produce faucets, because H62 copper has a higher copper content than H59 copper. So H62's corrosion resistance is better than H59.

But brass contains lead, which poses a health risk. (Starcraft Custom Builders, 2018) But through some subsequent processes, this problem can be solved.

Stainless steel is also a good material for making metal faucets. In metallurgy,

stainless steel is a general term for a type of alloy steel that usually contains 10% and 30% chromium. (Wikipedia) It is widely recognized as a non-toxic material and one of the internationally recognized metallic materials for implantable human body.

And stainless steel doesn't contain lead, which is a huge problem for today's environment. (Starcraft Custom Builders, 2018) The tap-specific stainless steel, called 304 stainless, contains 18% chromium and 8% nickel. Nickel gives steel a crystal structure that increases its strength and ductility. 304 stainless, also known as 18/ 8 stainless, stands for its chromium and nickel content. (Thyssenkrupp, 2017)

In addition, stainless steel faucets do not need to be treated to achieve rust-free effects, and the surface of steel faucets must be electroplated to ensure that copper does not rust due to contact with water and air. Stainless steel is also corrosion-resistant in acid, alkali, and salt solutions, allowing it to last longer.

Material properties:

Brass:

Physical Properties	Metric	English	Comments
Density	7.20 - 8.58 g/cc	0.260 - 0.320 lb/in ³	Average value: 8.49 g/cc Grade Count:390
Mechanical Properties	Metric	English	Comments
Hardness, Rockwell B	55.0 - 73.0	55.0 - 73.0	Average value: 65.1 Grade Count:6
Hardness, Rockwell F	22.0 - 133	22.0 - 133	Average value: 69.3 Grade Count:183
Hardness, Rockwell C	54.0 - 100	54.0 - 100	Average value: 68.7 Grade Count:64
Hardness, Rockwell H	8.00 - 240	8.00 - 240	Average value: 54.7 Grade Count:153
Tensile Strength, Ultimate	46.0 - 90.0	46.0 - 90.0	Average value: 68.7 Grade Count:13
Tensile Strength, Yield	124 - 1030 MPa	10000 - 150000 psi	Average value: 430 MPa Grade Count:389
Elongation at Break	34.5 - 683 MPa	5000 - 99100 psi	Average value: 255 MPa Grade Count:354
Reduction of Area	1.00 - 68.0 %	1.00 - 68.0 %	Average value: 32.0 % Grade Count:364
Modulus of Elasticity	40.0 - 80.0 %	40.0 - 80.0 %	Average value: 52.4 % Grade Count:53
Compressive Yield Strength	82.0 - 117 GPa	11800 - 17000 ksi	Average value: 106 GPa Grade Count:340
Poissons Ratio	82.7 - 260 MPa	12000 - 37500 psi	Average value: 144 MPa Grade Count:3
Fatigue Strength	0.280 - 0.375	0.280 - 0.375	Average value: 0.318 Grade Count:237
Mechanical Properties	22.0 - 360 MPa	3190 - 52200 psi	Average value: 106 MPa Grade Count:98
Shear Modulus	20.0 - 106 %	20.0 - 106 %	Average value: 40.8 % Grade Count:323
Shear Strength	35.0 - 44.0 GPa	5080 - 6380 ksi	Average value: 38.8 GPa Grade Count:284
Impact Impact	205 - 415 MPa	29700 - 60200 psi	Average value: 273 MPa Grade Count:208
Charpy Impact	11.0 - 45.0 J	8.11 - 33.2 ft-lb	Average value: 40.1 J Grade Count:9
Electrical Properties	Metric	English	Comments
Electrical Resistivity	0.00000318 - 0.0000290 ohm-cm	0.00000318 - 0.0000290 ohm-cm	Average value: 0.00000656 ohm-cm Grade Count:316
Magnetic Permeability	1.00	1.00	Average value: 1.00 Grade Count:3
Magnetic Susceptibility	-1.00e-6	-1.00e-6	Average value: -1.00e-6 Grade Count:40
Thermal Properties	Metric	English	Comments
CTE, linear	18.0 - 26.0 µm/m-°C	10.0 - 14.4 µm/in-°F	Average value: 20.1 µm/m-°C Grade Count:234
Specific Heat Capacity	0.375 - 0.380 J/g-°C	0.099 - 0.0908 BTU/lb-°F	Average value: 0.380 J/g-°C Grade Count:282
Thermal Conductivity	26.0 - 233 W/m-K	180 - 1620 BTU-in/hr-ft ² -°F	Average value: 124 W/m-K Grade Count:356
Solidus	809 - 1030 °C	1490 - 1880 °F	Average value: 917 °C Grade Count:295
Liquidus	809 - 990 °C	1490 - 1810 °F	Average value: 903 °C Grade Count:295
Phase Transition Temperature	890 - 1030 °C	1630 - 1880 °F	Average value: 931 °C Grade Count:295
Processing Properties	Metric	English	Comments
Annealing Temperature	260 °C	500 °F	Average value: 260 °C Grade Count:4
Hot-Working Temperature	425 - 750 °C	797 - 1380 °F	Average value: 540 °C Grade Count:278
Recrystallization Temperature	625 - 900 °C	1180 - 1650 °F	Average value: 770 °C Grade Count:250
Component Elements Properties	Metric	English	Comments
Aluminum, Al	0.00500 - 2.00 %	0.00500 - 2.00 %	Average value: 0.421 % Grade Count:8
Antimony, Sb	0.0200 - 0.250 %	0.0200 - 0.250 %	Average value: 0.0900 % Grade Count:25
Arsenic, As	0.0200 - 0.250 %	0.0200 - 0.250 %	Average value: 0.123 % Grade Count:3
Bismuth, Bi	0.500 - 2.20 %	0.500 - 2.20 %	Average value: 1.27 % Grade Count:3
Copper, Cu	55.0 - 95.0 %	55.0 - 95.0 %	Average value: 69.0 % Grade Count:391
Iron, Fe	0.0500 - 2.10 %	0.0500 - 2.10 %	Average value: 0.114 % Grade Count:322
Lead, Pb	0.0500 - 8.00 %	0.0500 - 8.00 %	Average value: 0.714 % Grade Count:337
Manganese, Mn	0.0800 - 1.80 %	0.0800 - 1.80 %	Average value: 0.797 % Grade Count:3
Nickel, Ni	0.200 - 1.00 %	0.200 - 1.00 %	Average value: 0.567 % Grade Count:6
Phosphorous, P	0.0100 - 0.200 %	0.0100 - 0.200 %	Average value: 0.0602 % Grade Count:28
Selenium, Se	0.0100 - 1.10 %	0.0100 - 1.10 %	Average value: 0.518 % Grade Count:3
Silicon, Si	0.00500 - 4.50 %	0.00500 - 4.50 %	Average value: 2.04 % Grade Count:11
Sulfur, S	0.0800 %	0.0800 %	Average value: 0.0800 % Grade Count:5
Tin, Sn	0.250 - 6.00 %	0.250 - 6.00 %	Average value: 0.994 % Grade Count:119
Zinc, Zn	4.00 - 43.5 %	4.00 - 43.5 %	Average value: 30.0 % Grade Count:391

Figure 4 (From:Overview of materials for Brass)

Stainless steel:

Chemical Compositions^{a)}

Element	% Present
Carbon (C)	0.07
Chromium (Cr)	17.50 - 19.50
Manganese (Mn)	2.00
Silicon (Si)	1.00
Phosphorus (P)	0.045
Sulphur (S)	0.015 ^{b)}
Nickel (Ni)	8.00 - 10.50
Nitrogen (N)	0.10
Iron (Fe)	Balance

a) Maximum values unless otherwise stated.

b) For machinability a controlled sulphur content of 0.015 - 0.030% is recommended and permitted.

Physical Properties

Property	Value
Density	8,000 Kg/m ³
Melting Point	1450 °C
Thermal Expansion	17.2 x 10 ⁻⁶ /K
Modulus of Elasticity	193 GPa
Thermal Conductivity	16.2W/m.K
Electrical Resistivity	0.072 x 10 ⁻⁶ Ω .m

Figure5 (from: thyssenkrupp)

Manufacturing processes:

With the development of science and technology, the faucet manufacturing process is more and more automatic, computer can control the machine. Today, most manufacturers use machining to make faucets. Mechanical processing refers to the process of changing the shape, size or performance of the work-piece by a kind of mechanical equipment.

At first, they use a machining process to shape the body into the required size and dimensions. This involves first cutting the bars into short slugs and automatically feeding them into a computerized numerically controlled machining center of multi-spindle and multi-axis design. This machine performs turning, milling, and drilling operations. It'll take about a minute to make a part.

Large metal faucets may require a lot of machining operations. For example, making the main body for some faucets needs to use a rotary machining center for more than 32 machining processes. In the case of processing with the proper machine, each process takes about 14 seconds. This means that the overall time takes about four minutes or more. (How products are made, 2019)

Finishes:

Because the stainless steel material itself is processed, the stainless steel faucet hardly needs finishing. But there may be lead on the surface of brass (which can be harmful to the human body), so the first step in finishes is to filter the lead on the surface.

Then, by electrolysis, a thin layer of nickel and chromium is attached to the surface of the faucet, which enhances the corrosion resistance of the metal faucet. In order to improve its durability, a layer of polymer will be added. (How products are made, 2019)

As for achieving smooth appearance of the faucet, the physical vapor deposition (PVD) method can be used. (Figure3)

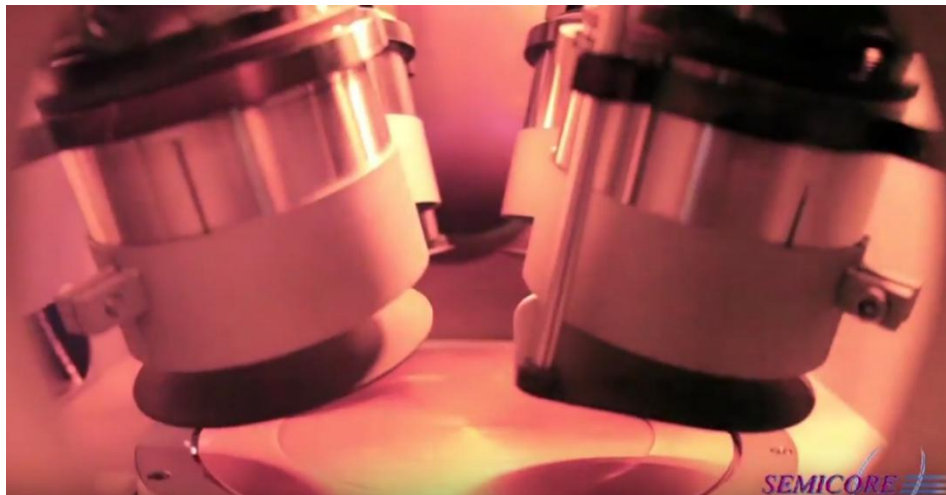


Figure6 (From: semicore equipment)

Assemblies:

When the assembly step is reached, some parts, such as: Spout O Ring, will be collected and installed by hand. The other part will be installed accurately with a rotating machine. Each installation will be stress tested.

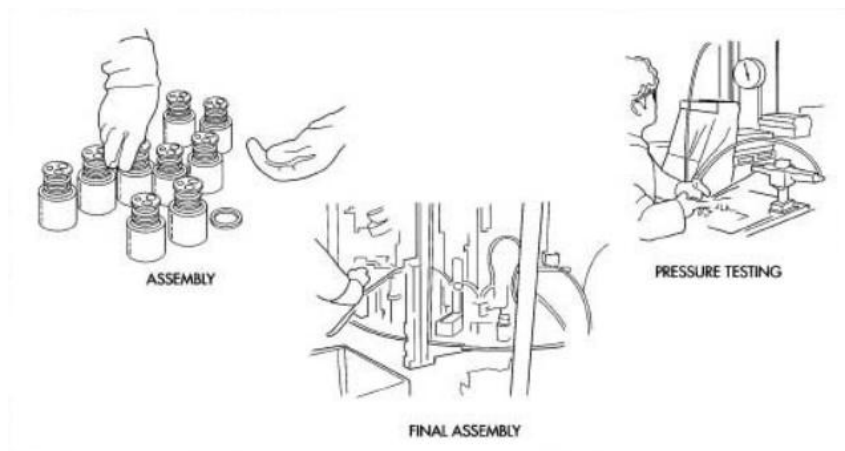


Figure7 (From:How products are made, 2019)

Alternative Material:

For the alternative material of the faucet, I choose to replace it with plastic. They are materials composed of various synthetic or semi-synthetic organic compounds, which can be molded into solid objects. (Wikipedia)

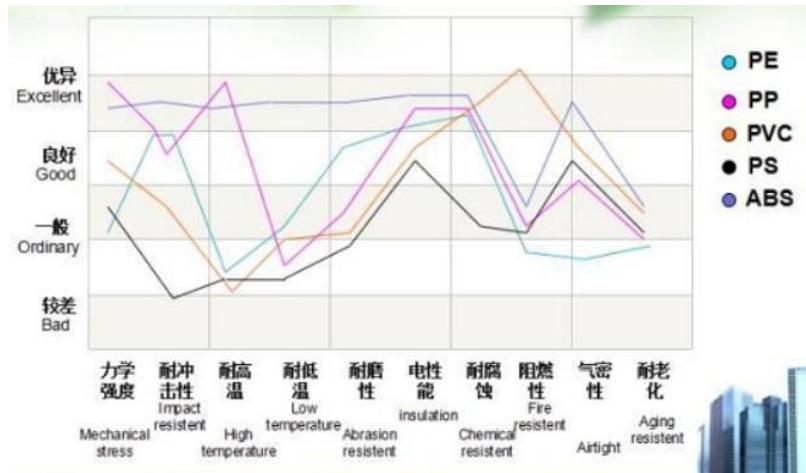


Figure8 (From: www.polymer.cn)

Different plastics have different properties. Combined with the mechanical stress, impact resistance, high temperature resistance, corrosion resistance, and aging resistance of various plastics, I chose to use PPR material to complete the manufacturing of the main body.

PPR(Polypropylene random copolymer)

Polypropylene random copolymer is a flexible and transparent polypropylene. It can provide good thermal and mechanical properties and chemical resistance, as well as transparency. It is widely used in packaging, plastic parts, reusable containers, laboratory equipment, automotive parts, pipes, etc. (Entec,2019)



Figure9 (From: indiamarket)

Material properties:

According to the Washington State Home Inspectors, the hot water from the kitchen faucet should not exceed 120 degrees Fahrenheit (about 49 degrees

Celsius) (buellinspections, 2011) Normally, the water flowing from the faucet would be less than or equal to that temperature. Otherwise, it will cause skin damage to the user. The melting point of the material, PPR, is about 150°C (as shown below), which is affordable as a hot pipe.

✓ PP Random Copolymer (6)	Flexural Modulus (kg/cm ²)	IzOD 23 °C (kg.cm/cm)	Melt Index at 230 °C and 2.16 kg (g/10 min)	Melting Point (°C)
> P655IM	9000	69	7	-
> P750J	12000	65	12	150
> P755JM	13000	64	20	150
> P838C	11260	-	28	157
> P851JO	12500	60	20	150
> P859JMR	10000	78	20	150

Figure10 (From: SCG)

Because people use water resources through faucets, whether the materials used by faucets is healthy or not becomes a matter of concern. The PPR material also features the following (Indiamarket):

Physically superior

Hygienically safe

Non-carcinogenic

At the same time, it can be used as a preservative box and other items can also be seen in its hygiene.



Figure11 (From: Total)

Typical Properties

Resin Properties	Method	Value	Unit
Melt Index(230°C, 2.16kg)	ASTM D1238	7.0	g/10min
Density	ASTM D792	0.90	g/cm ³
Tensile Strength at Yield	ASTM D638	280	kg/cm ²
Flexural Modulus	ASTM D790	9,500	kg/cm ²
Notched Izod Impact Strength(23°C)	ASTM D256	5.0	kg-cm/cm
Rockwell Hardness	ASTM D785	85	R-Scale

The values listed above are typical values for reference purpose only and shall not be construed as specifications.

Figure12(From: Topilene)

What I have to say is that as a plastic-a material that people usually think is not environmentally friendly, but he can also be recycled. The process of recycling involves sorting, collecting, cleaning, and reprocessing. (AZO cleantech, 2012)

And the resin identification code for PP is '5'.



Figure13 (From: DNR)

At the same time, PPR is lighter than brass, which making PPR faucets lighter and easier to transport and use.

Manufacturing processes:

Plastic injection molding is a process of melting plastic particles, once there is enough plasticity, it will be injected into the mold cavity under pressure, and then filled and solidified to produce the final product. (Protolabs)

First, the plastic particles of PPE are introduced into the injection molding machine. Melt plastic particles are transported to temperature-controlled split molds through a channel system of gates and runners. The screw melts (plasticises) the polymer, and also acts as a ram during the injection phase. Because of the shear effect of polymers, screw action also provides additional heating. Finally, the polymer is injected into the mold of a specific shape, and then the machine is separated from the cooling object to get the pipe we need. (BPF British Plastics Federation)

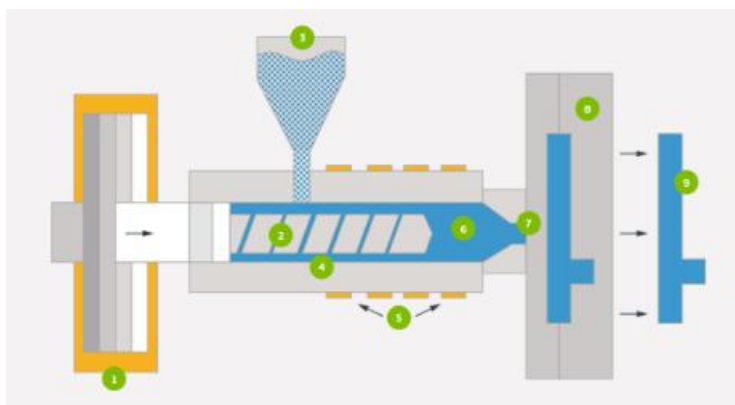


Figure14 (From: Protolabs)

PPR pipe hot melt connection is the most reliable, easy to operate, good gas tightness, high interface strength.

For the size requirements of the whole faucet, it is also feasible to consider the manufacturing method of injection moulding.

Design Considerations:

Some factors still need to be considered in the design of faucet (emachineshop) :

- Keep walls thin – typically between 1/32" and 1/10". This allows for proper cooling and reduces cost by minimizing use of material.
- To strengthen parts, instead of using thicker walls, use additional structures such as ribs.
- Round corners and edges wherever possible.
- When using a rib make it about half the main wall thickness.

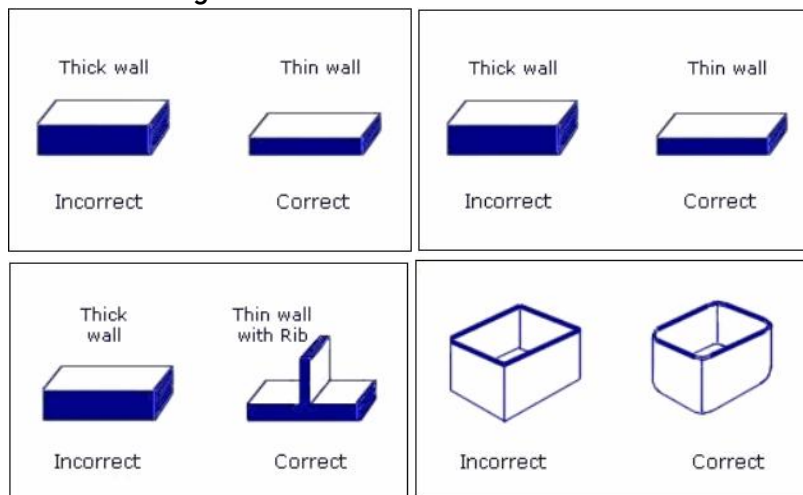


Figure15 (From: emachineshop)

Because the faucet is made from the injection moulding method, its shape allows for more different shapes than metal faucets.

Faucet parts are also more flexible to install and disassemble.

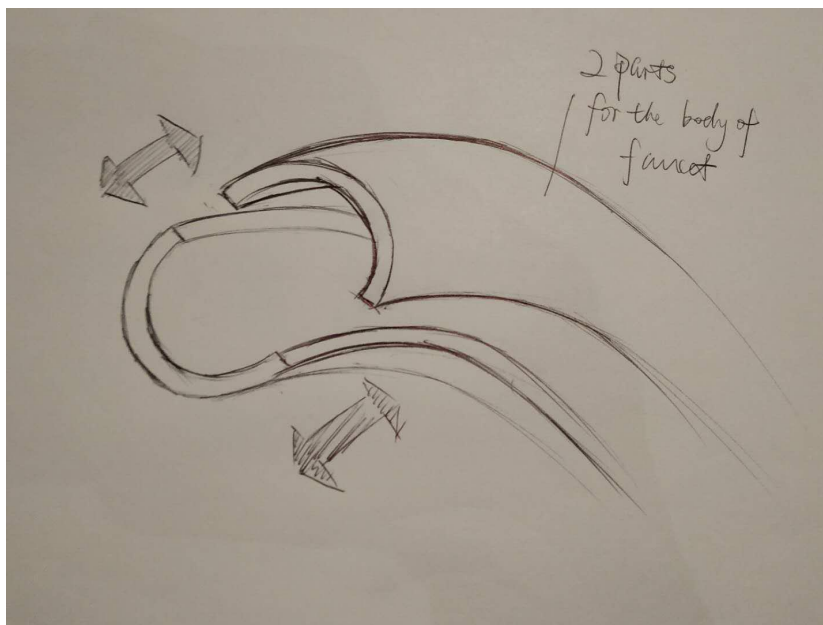


Figure16

Costs:

Both processing and plastic materials are cheaper than brass faucets today.

Density	/ kgm-3	905
Price / Tonne	/ £	680
Tensile Strength	/ Mpa	33
Tensile Modulus	/ Gpa	1.4
Elongation at Break	/ %	150
Hardness	/ Rockwell "R" Scale	90
Notched Izod Impact	/ kJm-1	0.07
Heat Distortion Temp (HDT) @ 0.45 MPa	/ °C	105
Heat Distortion Temp (HDT) @ 1.80 MPa	/ °C	65
Volume Resistivity	/ logÙm	19
Oxygen Index	/ %	17

Figure17 (From: BPFBritish Plastics Federation)

However, it has a disadvantage, which is that plastic materials age easily, which makes plastic faucets less durable than metal faucets. This means that, for a long time, more faucets need to be replaced.

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