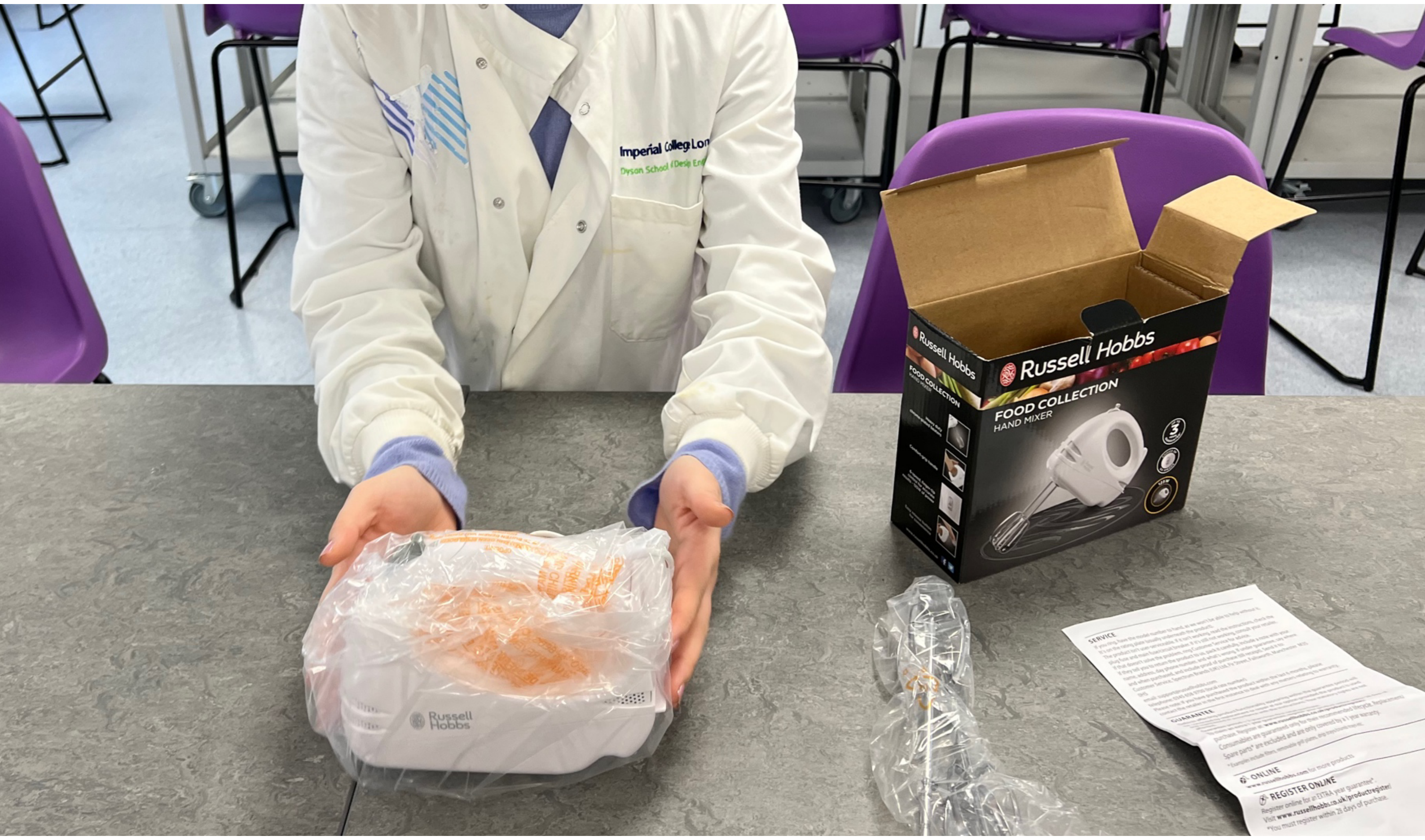
REVENG

Lisa Eco Innovations - Hand Mixer

THE CONSULTANCY



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Technical Summary

The consultancy has set out on a new venture with business partner Lisa Eco Inventions to help develop their brand-new electric food hand mixer product. Lisa Eco Inventions is a new and upcoming start-up working to create sustainable products at a budget friendly price. To redesign the product for Lisa Eco Inventions requirements, the consultancy performed a teardown of the 'Food Collection Hand Mixer' produced by Russell Hobbs. The consultancy also used a variety of techniques to work out what the components were made from and how they were manufactured to produce a full bill of materials within the product. CES EduPack was also used to perform an Eco Audit on the materials. Calculations were also performed to work out the embodied energy and CO_2 footprint. The result should be a product that retains the original functionality of the food mixer but with these new requirements in place with a strong consideration on sustainability.

Following the report, the consultancy strongly advises Lisa Eco Innovations to **substitute PLA for ABS, angle the beaters in operation** and **implement a QR Code Instruction Pack** in their anticipated food mixer product.

Introduction

The product is a kitchen appliance in the budget price range (£12 (1)). This could mean that the producer, Russell Hobbs, may have used cost saving techniques in manufacture and materials that the consultancy had to investigate. The hand mixer has a switcher allowing 6 different speeds to be selected. It also features detachable beaters allowing for service if a beater fails. The product is also mains powered. On average the product received a 4.5 (1) star review from customers. Typical customer complaints included the fact that there was no low setting, centre of gravity whilst whisking being too far forward, can get hot under use and frequent motor stalls. These complaints were considered in the reconstruction of the food hand mixer that Lisa Eco Innovations requested.

At a glance, it is clear that there is ventilation holes that have been cut out to keep the motor inside the product cool. It is also clear that product makes use of double insulation where there is no ground wire present to prevent electric shock as the double plastic layer will act as insulation.

The final redesigned product should be primarily **sustainable**, **reliable** and **cost-effective**. These are the three metrics that the consultancy will look to optimise in the report.

Figure 1: Russell Hobbs Food Mixer before tear-down

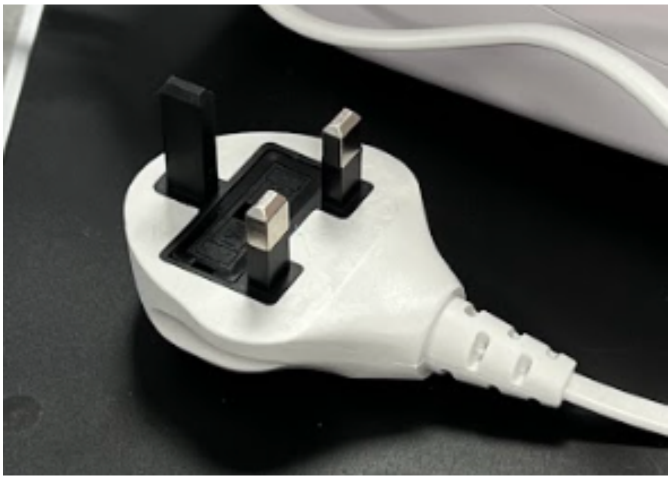


Figure 2: Lack of ground pin on plug showing appliance is double insulated

Background

The product is a food mixer, designed to improve upon the experience of mixing by hand while cooking. Hand mixers are better suited to lighter, occasional use. The Russell Hobbs mixer has a motor with 125W (2) of power that can have go at a maximum of approximately 1000RPM. Some food mixers feature different attachment options. These can be used for different mixture types giving a different texture or in some case they are required due to the high viscosity.

Figure 3: A handheld food mixer promotional image showing the different attachments it comes with. (3)

There are mainly two different types of food mixers, stand and handheld. Hand mixers are better suited to lighter, occasional use whilst stand mixers are more flexible and used both in consumer and more commonly professional kitchens. Stand mixers also often feature more powerful motors with better cooling. There is also likely a greater range of speeds on a stand mixer. The product we have however is a handheld mixer which is also cheaper to produce and purchase. Another alternative to these electronic solutions are the more readily available manual mechanical mixers that rely on a wheel with a handle (exerting a greater force) being spun by the user to turn the whisk.

The whisk consists of four main components, a 125W motor, two beaters that are hot swappable, a speed control switch allowing you to adjust on the fly and an eject button to remove the beaters.

Figure 4: The two most highly rated Amazon.co.uk Food Mixers

The food mixers pictured above are examples of competitor products to the Russell Hobbs food mixer. The left-hand model appears to be a more premium ‘multi tool’ style unit with different attachment options allowing you to blend, puree, whisk and mix with a compact battery powered device. The price point is more than double what the Russell Hobbs product is selling for. The other option sold by Salter, a direct competitor to Russell Hobbs was approximately £12 more. This unit appeared to be more reliable from customer feedback reviews on Amazon and ‘get the job done’ whilst the Russell Hobbs users sometimes faced frustration. It also appeared to have a more powerful motor at 300W. Typically food mixers and similar budget kitchen appliances are made from thermoplastics such as ABS, PE and PP. Stainless steel is often used for the beaters. Injection moulding is often used for the casing as polymers are light weight and can be easily manufactured on a mass market scale. For any kind of mixer, investment casting is often used to produce the complex attachment shapes that might be required. Wires are manufactured using a wire drawing method and typically consist of copper. Food mixers are often expected to have an expected lifetime of at least 5 years and typically last much longer than that.

Method

The first step in the process was to simulate use of the product. A test subject held the product in their hand and evaluated the ergonomics and stated their feelings about the usability of the product. The consultancy then begun the deconstruction. As a safety precaution, the fuse of the product was removed to reduce the risk of live electricity being passed through what would become an unsafe product. To open the product, first screws were removed that secured the outer housing (Figure 8). The attachments were also removed. The speed switcher was pulled out of place as this was free to more once the two components for the top and bottom of the mixer had been split. A soldering iron was required to remove the 'Heat Staking' that had been used to secure the PCB to the bottom shell.

Figure 5: PCB held in place via melted plastic

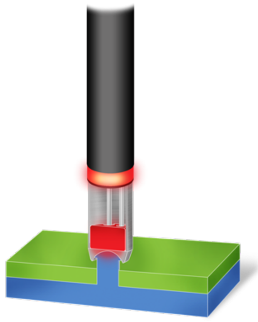


Figure 6: Heat Staking (4)

The soldering iron was also used to remove the solder connecting the wires between different components (Figure 9). The different plastics were burned under a fume extractor or placed in water to work out their type using the Plastics Identification Chart (see appendix 1). We also weighed and created a spreadsheet entry for each component within the product for our bill of materials. A magnet was used for the metal components to help narrow down their type.

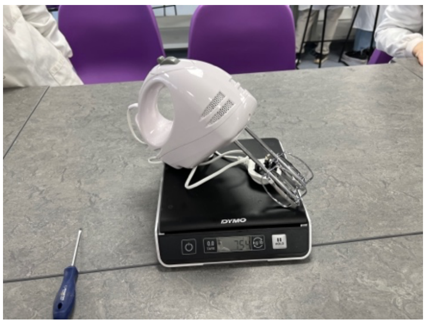


Figure 7: Weighing the product

Figure 8: Separating the two components

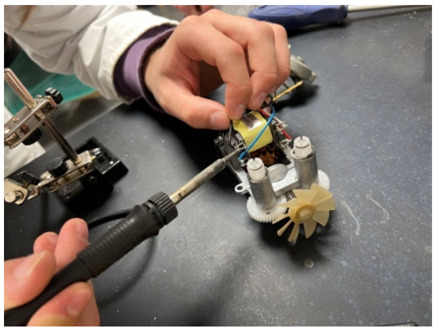


Figure 9: Removing connection wires

Discussion

Design of the Product

The case is ergonomically formed to fit the shape of either left-handed or right-handed people making it an inclusive design. It is designed to be used with only one hand. The case is injection moulded and splits into two parts held together by screws. Two air vents are present at the front of the product. There is a fan that is attached to the motor of the product that cools the electronics during use. The product is electronic and requires no significant manual activity to operate. There is a switch that allows you to use your finger to quickly switch between options. Each switch open simply switches a copper pad between different options of resistances completing the circuit. The product is easy to work out how to use for any kind of user and does not require any training. The device felt like it would last a long time. Customers did complain that the product got hot after a few minutes of use. It's more time consuming to mix by hand and requires more effort so this product is ideal as a time saver. The product interior also has two heavy metal parts to add weight to the product as if it were too light it would be hard to control with the high-speed forces from the motor. The motor is connected to a worm drive system which is a shaft connected to two gears that spins the beaters. The beaters also had springs that help absorb the vibrations placed upon the product making it more comfortable for the user.

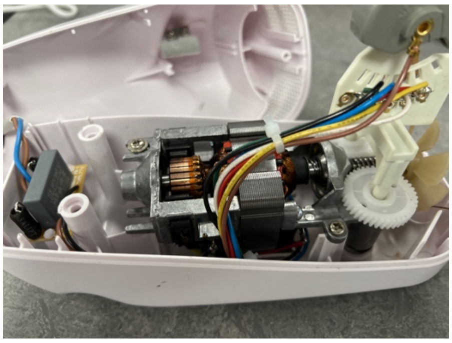


Figure 10: The metal components adding weight to the product

Figure 11: Element on the switch making for a more tactile experience

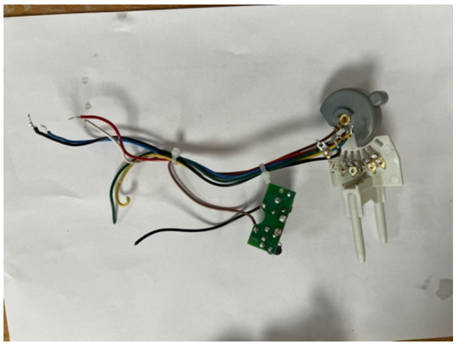


Figure 12: Switcher copper pads used for switching speeds

Bill of Materials

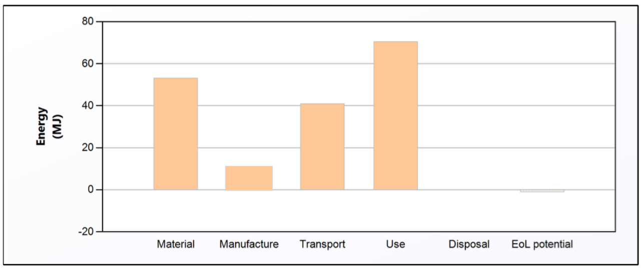
CES EduPack's Eco Audit function was used to produce a bill of materials. This gives a breakdown of the embodied energy and the total carbon footprint produced by each material. The input data was produced during disassembly which was recorded into a spreadsheet. The level 1 database within CES EduPack was used. In most cases, upon disposal most materials were assumed to go to landfill. Apart from the packaging that was assumed to be recycled. Any items with a very low weight were removed from the summarised bill of materials. The expected lifespan of the product was assumed to be 5 years in line with consumer regulation.

Table 1: Summarised bill of materials (full copy available in appendix)

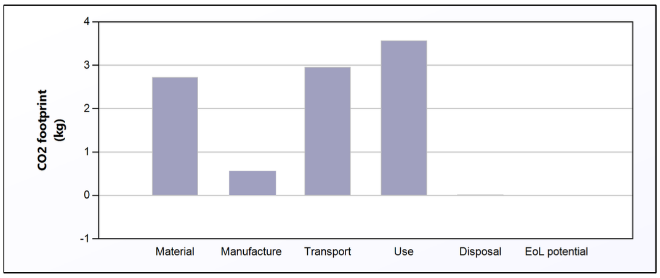
Component	Quantity	Mass/unit (g)	Material	Manufacturing Process	Embodied Energy/MJ	Total CO2 Footprint/kg
Whisk blade	2	44	Carbon Steel	Investment Casting	2.85	0.21
Box	1	82	Cardboard	Included in material value	2.31	0.1
Case part 1	1	85	ABS	Injection Moulding	7.95	0.3
Coloured wires	1	8	Copper	Wire drawing	0.52	0.03
Speed switch	1	19	ABS	Injection Moulding	1.78	0.07
Gears	2	6	Nylon	Injection Moulding	1.71	0.08
Motor and fan	1	146	50% copper, 25% steel, 25% zinc	Various incl. Casting and Wire Drawing	9.41	0.59
Coil and magnet	1	131	Copper	Wire drawing	8.45	0.53
Motor end piece	1	25	Zinc	Casting	1.26	0.1
Plastic with Blue resistors	1	10	ABS	Injection Moulding	0.93	0.04

Cable and plug	1	89	Silicone and wire	Injection Moulding and Wire Drawing	0.12	0.01
Case part 2	1	108	ABS	Injection Moulding	10.1	0.39
Case part 3	1	15	ABS	Injection Moulding	1.4	0.05

Embodied Energy and CO_2 Footprint



	Energy (MJ/year)
Equivalent annual environmental burden (averaged over 5 year product life):	33



	CO2 (kg/year)
Equivalent annual environmental burden (averaged over 5 year product life):	1.85

CES EduPack was used to generate an embodied energy and carbon footprint graph. Embodied energy is the energy consumed throughout the life cycle of the unit. An example of a material that could be processed would be the stainless steel used for the beaters. The highest energy cost is likely to come from the extraction of the materials from the earth rather than the manufacturing. As the expected lifespan of the product is 5 years, CES EduPack spreads this energy over this period reducing the overall impact. It is likely that the product may last longer than 5 years which would further decrease the embodied energy.

The CO_2 follows a similar pattern in terms of most CO_2 being produced during the extraction phase. Additionally, a large amount of CO_2 will be produced during transport. In CES EduPack the consultancy stated that the product would undergo a 7836km flight to the UK from China, followed by a 60km delivery truck journey and then a 6km delivery vehicle journey.

The most significant energy and CO_2 usage occur during actual usage of the product with energy values and CO_2 footprint of 33MJ/year and 1.85kg/year respectively.

Materials and Manufacturing Methods

Induction Motor - Casting and Wire Drawing – The motor is the main mechanical and electrical component within the product. To manufacture a motor, very thin wires are drawn out of copper and wrapped as coils around the core of the motor often made from plastic. Wire drawing consists of pulling a wire a die that reduces the materials cross sectional area. As copper is a great conductor it is used within the motor. As a current is placed across the coil a magnetic field is produced causing it to become attracted towards the centre, the current is then reversed for the motor to keep spinning. The motor casing is made using Casting. Casting is the process by which the heavy motor housing is made, where molten metal (steel) is poured into premade moulds for the exact shape required.

Screws, Washers – Stamping – Stamping is a part produced in a sheet metal operation. Screws, washers, nuts, and bolts are often manufactured using this technique. A punch and die are used to set the sheet of metal into the desired format.

Cables – Wire Drawing and Extrusion – Silicon is wrapped around the copper wire as it is extruded. The silicone is heated so it becomes hard after cooling protecting the wire from damage.

Beaters – Investment Casting – A wax model is created for the whisk beater that the molten metal can be poured into. Patterns are produced that are attached to a sprue to produce a pattern tree. The pattern tree is coated with a thin layer of refractory material. The mould is then formed by covering the tree with a refractory material to make it rigid. The mould is then flipped upside down and heated to melt the wax. Preheating then occurs to a high temperature as molten metal is poured to solidify. After this, the mould is broken away from the finished casting to give the result. (5)

Case – Injection Moulding – The case of the product is injection moulded. This means a mould has been produced for each component. The moulds are typically expensive to produce so they are often only used when a large quantity of products is required. The mould is closed and clamped whilst a shot of melt is injected into the mould. Quickly the plastic begins to solidify and harden in the shape of the mould. Pressure is increased to ensure the melt matches the mould exactly. The screw is rotated and retracted with the non-return valve to allow the polymer in. Finally, the mould is opened, and the part is removed. (5)

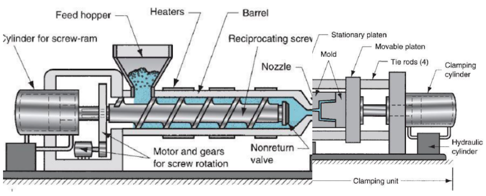


Figure 13: Injection moulding unit

ABS - The product is made of an ABS material in a plain white colour. ABS was likely chosen by the manufacturer because it is robust and can withstand impact damage quite well in addition to being fairly cost effective. ABS plastic also acts as an insulator preventing the user from burning themselves.

Stainless Steel – Stainless steel is more corrosion resistant than normal steel. The beaters of the whisk are made from stainless steel as they will be subjected to many foreign substances during usage and may become wet for long periods of time.

SDS Ratings for Material

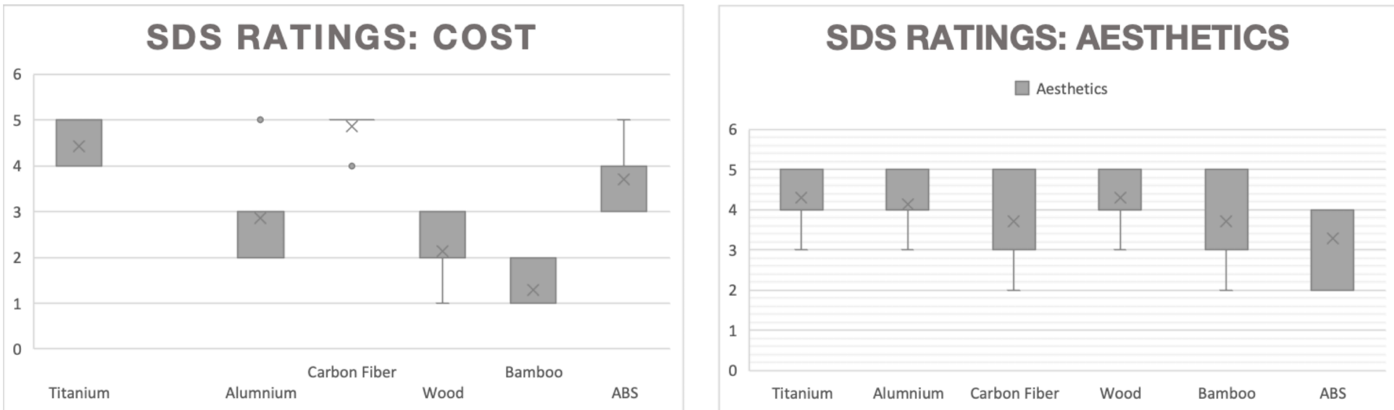


Figure 14: Data from an SDS survey I performed with ABS added as an additional material post survey.

Using a combination of previous data collected by the consultancy and new data for new materials not held within our dataset we asked participants to rate the aesthetics and cost of Titanium, Aluminium, Carbon Fibre, Wood, Bamboo and ABS. ABS was the result that the consultancy was particularly interested in as it was the material the food mixer was found to be made from using the plastic identification test. Interestingly it is the only material that never received an ‘excellent’ aesthetic rating however participants also felt it was more expensive. This prompted the consultancy to pursue potential alternative options in the Reverse-Engineered Solution.

Reverse-Engineered Solution

The objective of the teardown was to break down the product to understand how it could be improved to make it more sustainable and effective for Lisa Eco Innovations. Below are some of the options that the consultancy considered for this improvement to the product.

Manually Operated

One of the ideas the consultancy produced for the new eco innovations product was a manual operation option of the food mixer. This would be far cheaper to produce as no more costly parts would be required and the manufacturing process would be far simpler. All that would be required would be an investment casting of the stainless-steel whisks and mechanisms followed by construction of the components. The product would also not require power. However, consumer feedback soon revealed that this would be too much manual work compared to a traditional electric food mixer and sales were likely to be poor, so this idea was scrapped.

PLA

Another idea the consultancy had on improving the product for Lisa Eco Innovations was the substitution of PLA for ABS. PLA is a plant-based polymer often used for 3D printer filament. To evaluate the properties of PLA in comparison to other similar polymers, CES EduPack was used to generate an Ashby plot to compare the Vickers hardness (17 – 22 HV) against the Price of the material per kilogram. PLA was found to be one of the hardest plant-based polymers with a reasonable GBP/kg of 2.01 – 2.37. Plant-based polyethylene was also considered but the consultancy decided against it due to its lower Vickers Hardness (5.4 - 8.7 HV). In comparison, the current material ABS has a GBP/kg of 1.27 – 1.85 and Vickers Hardness (10 – 15 HV). The price increase is acceptable for the performance and sustainability gains that would be achieved by switching to PLA if this change were to be made. Metals from the SDS survey were discarded as the consultancy did not feel they were appropriate for the product as they would increase the weight or make the product too expensive for the Lisa Eco Innovation budget customer. PLA has a melting point of approximately 180-200 degrees (ABS is 200 degrees) however the product will not be reaching these temperatures even under high loads. This switch substantially changes the embodied energy of the material stage from ~60MJ to ~20MJ.

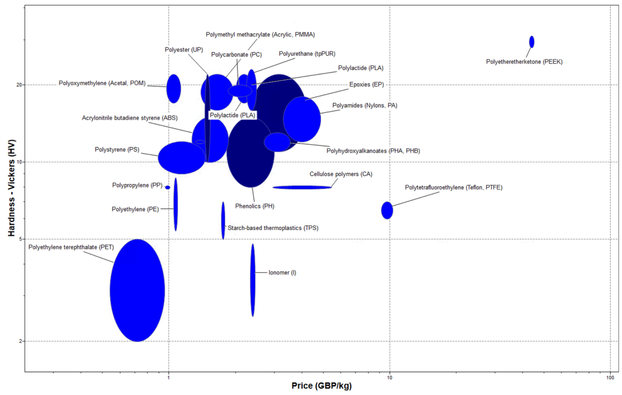


Figure 15: Ashby plot of Price vs Hardness

Figure 16: Lego elements made from plant-based polyethylene

Angle the Beaters

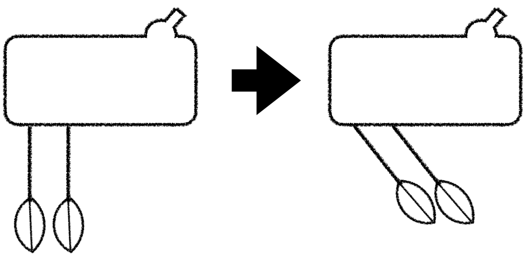


Figure 17: Proposed improvement to beater angle

Customer feedback stated that the centre of mass of the product seemed off-centre and that it was unergonomic to use as the beaters did not match the curvature of the bowl. This more efficient design means that mixing will be more time efficient meaning less energy usage, less wear on the motor, less heating and the user will not need to work for as long increasing customer satisfaction.

QR Code Instruction Pack

Figure 18: Packaging of the food mixer

Within the product there was a vast amount of packaging, warranty leaflets and instructions. A QR code that could be scanned on the box of the product with digital instructions would offer a substantial paper reduction in Lisa Eco Innovations next hand mixer product. There would also be a cost saving aspect to the move as well. Consumers are now familiar with the concept after the COVID-19 pandemic made such technology much more prevalent. The consultancy estimates that this will save 2p per unit based on the wholesale cost of paper. (6) Additionally, the product is fairly simple to operate even without the Instructions for users that don't want to scan the QR code.

Following the investigations listed above the consultancy strongly advises Lisa Eco Innovations to **substitute PLA for ABS, angle the beaters** and **implement a QR Code Instruction Pack** in their anticipated food mixer product.

How do these changes affect the manufacturing process?
In most cases, these changes have limited impact on the current procedure or in fact remove procedures all together. The PLA substitution will still use the exact same injection moulding technique that Lisa Eco Innovations has used before. The change of angle of the beaters will have a more significant production review where moulds will need to be remade to adapt for the new location of the beaters. The casing may need to be redesigned ergonomically as well to ensure a stable centre of mass. The QR Code Instruction Pack will eliminate the paperwork production line and require a simple marketing change on the external inkjet printing applied to the box.

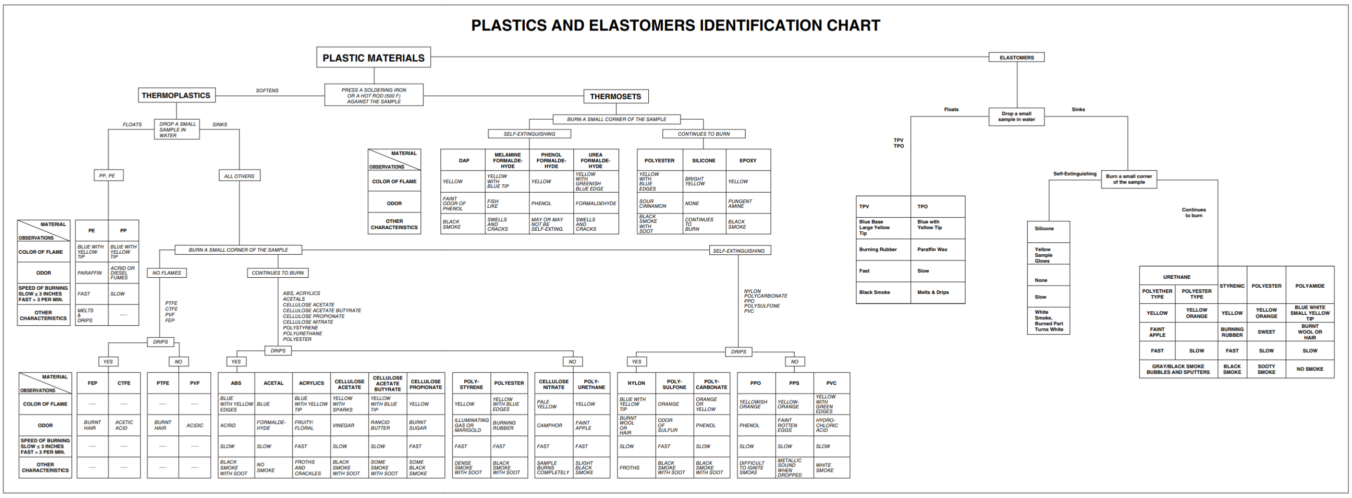
Conclusion

The Consultancy has thoroughly investigated all parts of the Russell Hobbs food collection mixer when coming to its proposed changes that should be implemented in their anticipated food mixer release. Through careful and precise teardown methodology the Consultancy was able to understand exactly how the food mixer was constructed and what manufacturing methods and materials were used. A display board of the disassembled components can be found in the appendices. The current footprint in energy and CO_2 was 33MJ/year and 1.85kg/year respectively. Using an external forecasting consultancy, the consultancy was given a predicted Y/Y for the FY24 sales % increase of 10% which would be a huge boost to Lisa Eco Innovations Revenue.

The most notable materials used were ABS and Stainless Steel that made up the casing and beaters respectively. The proposed changes were to **substitute PLA for ABS, angle the beaters** and **implement a QR Code Instruction Pack**. These options all are realistic, achievable and will have a significant impact on both the customer experience and Lisa Eco Innovation's brand image as being the most budget friendly sustainable brand.

Appendix

1. Plastics Identification Chart



The Plastics identification technique is laid out in flowchart for eash step-by-step identification by process of elimination. This is shown in the plastics Identification Chart. There are some basic guidelines one must follow in order to simplify the procedure. The first step is to determine whether the material is thermoplastic or thermoset. This distinction is made by simply probing the sample with a soldering iron or a hot rod heated to approximately 500°F. If the sample softens, the material is thermoplastic. If not, it is thermoset. The next step is to conduct a flame test. It is desirable to use a colorless Bunsen burner. A matchstick can also be used in place of a Bunsen burner. However, care must be taken to distinguish between the odor of the materials used in the match and the odor given off by burning plastic materials. Before commencing the burning test, it is advisable to be prepared to write down the following observations:
1.Does the material burn? 2.color of flame 3.Odor 4.Does the material drip while burning 5.Nature of smoke and color of smoke. 6. The presence of soot in the air. 7. Self-extinguishes or continues to burn. 8. Speed of burning--fast or slow
To identify the material, compare the actual observations with the ones listed in the flowchart. The accuracy of the test can be greatly improved by performing similar tests on a known sample. While performing the identification tests, one must not overlook safety factors. The drippings from the burning plastic may be very hot and sticky. After extinguishing the flame, inhale the smoke very carefully. Certain plastics like acetals give off a toxic formaldehyde gas that may cause a severe burning sensation in the nose and chest.

2. Full bill of materials (removed from original are indicated in red)

Part Number	Component	Quantity	Mass/unit (g)	Material	Manufacturing Process	Embodied Energy/MJ	Total CO2 Footprint/kg
1	Whisk blade	2	44	Carbon Steel	Investment Casting	2.85	0.21
2	Large packaging	1	10	PE-LD	Included in material value	0.8	0.02
3	Box	1	82	Cardboard	Included in material value	2.31	0.1
4	Case part 1	1	85	ABS	Injection Moulding	7.95	0.3
5	Coloured wires	1	8	Copper	Wire drawing	0.52	0.03
6	Grey box	1	7	Silicone	Included in material value	0.87	0.05
7	Small packaging	1	3	PE-LD	Included in material value	0.24	0.01
8	Speed switch	1	19	ABS	Injection Moulding	1.78	0.07
9	Cable holder (transparent)	1	<1	PTFE or PVF	Injection Moulding	0.3	0.02
10	Black springs	2	1	Hardened steel	Drawing and Cold Winding	0.06	0
11	Small silver washers	2	<1	Carbon steel	Stamping	0.06	0
12	Gears	2	6	Nylon	Injection Moulding	1.71	0.08
13	Motor and fan	1	146	50% copper, 25% steel, 25% zinc	Various incl. Casting and Wire Drawing	9.41	0.59
14	Horseshoe clip	2	<1	Stainless steel	Casting	0.15	0.01
15	Spring clips	2	<1	Hardened steel	Casting	0.06	0
16	Coil and magnet	1	131	Copper	Wire drawing	8.45	0.53

17	Large washers	2	1	Carbon steel	Stamping	0.06	0
18	Long screws	2	3	Low-medium carbon steel	Stamping	0.18	0.01
19	Motor end piece	1	25	Zinc	Casting	1.26	0.1
20	Plastic with Blue resistors	1	10	ABS	Injection Moulding	0.93	0.04
21	screw for motor end piece	1	2	Low-medium carbon steel	Stamping	0.12	0.01
22	Small magnets	2	1	Iron	Casting	0.06	0
23	Long plastic washers	2	<1	ABS	Non-metallic stamping	0.09	0
24	Copper small spring	2	1	Copper	Drawing and Cold Winding	0.06	0
25	Grey piece with holes	1	1	ABS	Injection Moulding	0.09	0
26	Instructions	1	9	Paper	Included in material value	0.25	0.01
27	Self-tapping screw	3	1.3	Low-medium carbon steel	Stamping	0.1	0.01
28	Philips head screws 1	2	1.5	Low-medium carbon steel	Stamping	0.1	0.01
29	Philips head screws 2	1	2	Low-medium carbon steel	Stamping	0.06	0
30	Philips head screws 3	2	1	Low-medium carbon steel	Stamping	0.06	0
31	Philips head screws 4	2	1	Low-medium carbon steel	Stamping	0.06	0
32	Philips head screws 5	1	1	Low-medium carbon steel	Stamping	0.03	0
33	Plug cover	1	1	PE-LD	Injection Moulding	0.08	0
34	Cable guide casing (main power cable entrance cover)	1	1	Silicone	Extrusion	0.12	0.01
35	Wire cable tie	1	1	Aluminium	Stamping	0.2	0.01
36	Cable and plug	1	89	Silicone and wire	Injection Moulding and Wire Drawing	0.12	0.01
37	Fuse holder	1	1	PPO	Injection Moulding	0.08	0
38	Fuse	1	2	Zinc	Wire drawing	0.1	0.01
39	Case part 2	1	108	ABS	Injection Moulding	10.1	0.39

40	Case part 3	1	15	ABS	Injection Moulding	1.4	0.05

Exploded Teardown

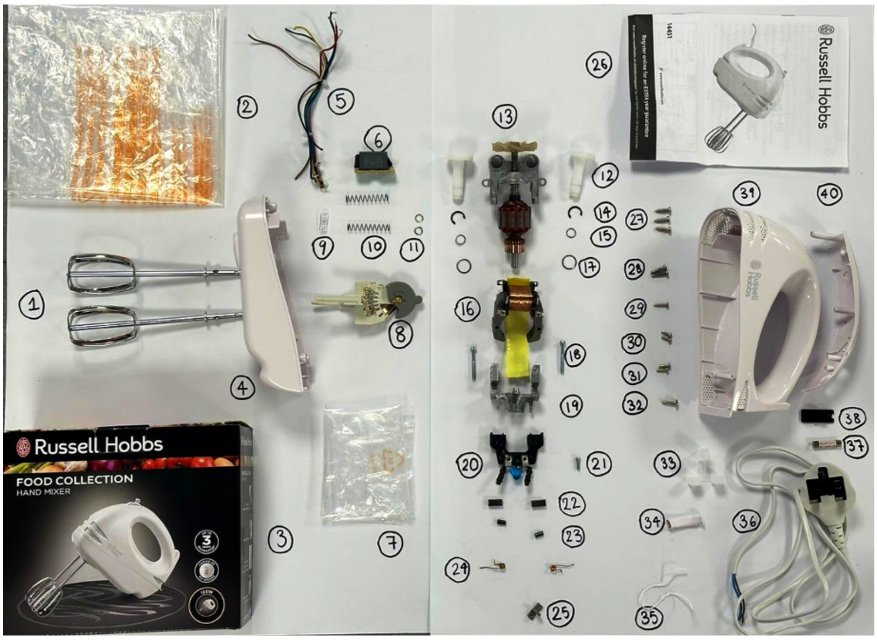


Figure 19: Exploded view of the hand mixer. Numbers ref full bill of materials found in appendices.

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