RevEng Report: Kiprim Electic Screwdriver

Wancerski, Krzysztof
Materials and Manufacturing
CID: 02201834

1 TABLE OF CONTENTS

2 TECHNICAL SUMMARY

The Kiprim electric screwdriver has been improved upon the completion of a thorough reverse-engineering process. Firstly, the screwdriver was torn down into its primary components, a teardown board was created alongside a bill of materials. This bill consisted of the mass, material, manufacturing process, the total embodied energy, and the CO2 footprint of each part. The product's total embodied energy was calculated to be 40.0 MJ, and the total CO2 footprint was determined to be 2.7 kg. These values were obtained through the use of the eco-audit tool on CES Edupack during the analysis of the bill of materials, which allowed the team to identify the most significant contributors to the product's environmental impact. The components with the highest environmental impact, namely the outer case, handle grips, screwdriver bits, and screwdriver holder, were selected for improvement.

During the improvement phase, priority was given to meeting the client's requirements while minimizing additional environmental impact. The primary design change was the addition of an electroless-plated layer to the ABS plastic to improve the product's aesthetics. Furthermore, increasing the size of the hand grips was recommended to enhance usability, while the removal of the USB cable from the packaging was suggested to increase sustainability.

3 INTRODUCTION

The client, Homer’s Handymen, has asked to reverse engineer the Electric Screwdriver. His requirements were stated as reducing the product’s environmental impact and ensuring the redesigned product matches Homer’s company values.

Firstly, the total embodied energy and CO2 footprint of the product were determined. Additionally, Homer’s principles can be summarised by the company’s motto - “buy low, sell high”. Therefore, it was established that the proposed reverse-engineered solution needs to place importance on the product’s embodied energy and CO2 footprint, as well as it was required for the product to have a premium feel at a low cost for the manufacturer.

4 Background

4.1 Market Overview

4.1.1 Definition

In general, a handheld electric screwdriver can be defined as a portable power tool that is designed for driving and removing screws. It usually has an electric motor and a chuck or collet that can accommodate different screwdriver bits. When a screw is driven or removed, the tool works by converting electrical energy into rotational motion, which is then transmitted to the screwdriver bit. To help avoid overtightening or stripping of screws, some handheld electric screwdrivers may also have adjustable torque levels. (1)

Figure 1 - An Illustration showing the Electric Drill with its main features listed.

4.2 Product Overview

4.2.1 Description

The Kiprim Electric Screwdriver was designed as a low-power and low-cost product for home use. It can be found listed on Amazon for a very competitive price of £14.44 and, as stated by the manufacturer, it is designed for "hanging and adjusting pictures, assembling furniture, fixing toys and repairing electrical devices". The main features of the product are the rechargeable battery, the various, magnetic screwdriver bits, and a front LED work light. These features, and the product, can be seen in Figure 1. (2)

4.2.2 Technical Specification

Table 1 - Comparison of specifications between existing products and the Kiprim drill

Property and Description	Typical Range	Kiprim Drill
Voltage	Usually around 3.6 V, but higher voltages of up to 12 V or 18 V can offer more torque for tasks that require more force.	4 V
RPM – Revolutions Per Minute	Everyday screwdrivers only need 200-400 rpm, while professional combi drills may require 3000 rpm or more.	Not stated.
Torque	Electric screwdrivers typically have 3-5 Nm of torque.	Not stated.

4.3 Existing Premium Product Comparison

In Figure 2, a Bosch IXO Cordless Screwdriver can be seen. Despite looking similar to the Kiprim product, it is listed for a 3 times higher price (£49) on Amazon. (3)

The two products have very similar features such as an LED work light, a forward and reverse button, a trigger for operation, charging via a USB port, and a set of screwdriver bits included. It has a 3.6 V motor and spins at the speed of 235 rpm and has a torque range between 3-5.5 Nm.

This price difference can be partly attributed to the materials and manufacturing techniques used in the Bosch driver. The Bosch product can be seen to feature much more of the easy to grip material and plastics which are meant to imitate the appearance of steel.

Figure 2 - A Premium Bosch Electric Screwdriver

5 METHOD

5.1 TEARDOWN BOARD CREATION

Firstly, the screwdriver was tested out by the team to get a feel of how the product performs its primary function. The manual was used by the team to get an understanding of how to operate the product safely and effectively.

Once all the group members were satisfied with their testing, the team proceeded to teardown the product. Firstly, all outer screws were unscrewed, and the outer casing of the electric screwdriver was removed. Upon opening the screwdriver, it was apparent that there was a substantial amount of grease inside which made the further process messy. Then all of the loose pieces such as the trigger and LED casings were removed.

After the removal of all loose pieces from the inside, it was now necessary to remove the electronics. This was done by undoing the clips by which the PCB was fixed to the case. Once this was complete, it was now possible to remove the geartrain and disassemble it into primary parts. Then lastly, the over moulded grip plastic was removed from the outer casing using a significant amount of force.

Figure 3 - The screwdriver partly disassembled.

Once this was complete and the product was disassembled into primary parts, these were laid out and labelled. Then a picture was taken to create the teardown board. See Appendix for pictures of this process.

5.2 MATERIAL IDENTIFICATION

The initial identification was done by inspection of the parts. These were split into three categories: plastics, metals, and other materials. The identification process differed for all of these, as outlined below.

Figure 4 – One of the plastic gears being tested.

5.2.1 Plastics

First, the part was checked for any indications such as a label as to what the material of that part is. This was the case for the outer casing of the screwdriver and allowed us to identify that it was made of ABS with very high certainty.

Otherwise, the Plastics Identification Sheet (see the Appendix) was followed to identify plastics with a medium level of certainty.

5.2.2 Metals

The process for metals was significantly different. There was no readily available metal identification process like the one for polymers. It was therefore decided to use secondary research to find similar products and investigate if they have material information provided. This method has a very high uncertainty associated with it.

5.2.3 Other

Other materials could not be placed into either of these categories. These included the PCB, the motor, and the cables. These were identified as electronics for the purposes of the Eco Audit.

5.3 ECO AUDIT

Once all of the parts were tested for material, they were put on a balance to determine their respective masses. This information was then inputted into CES EduPack which was able to calculate the product's total internal energy as well as its CO2 footprint. In case there was no corresponding material/production process the closest available option was chosen.

6 DISCUSSION

6.1 BILL OF MATERIALS

Using the method described above, a Bill of Material was produced using the CES software. It was decided not to include a further breakdown of the electronic components of the product, as their analysis and improvement were outside of the scope of this project. The teardown of the product can be seen in the appendix.

Table 2 - The Bill of Material for the Electric Screwdriver

Part Number	Part Name	Quantity	Mass (g)	Total Mass (g)	Material and Confidence	Manufacturing Method and Confidence	Embodied Energy (MJ)	Carbon Footprint (kg)
1	Handle Grips	2	0.010	0.02	Silicone elastomers | M	Injection Moulding | M	1.239	0.065
2	Outer Case	2	0.038	0.076	Acrylonitrile butadiene styrene | H	Injection Moulding | H	7.105	0.272
3	Switch	1	0.002	0.002	Polypropylene | M	Injection Moulding | M	0.136	0.006
4	Clear Pieces	2	<0.001	<0.001	Polycarbonate | M	Injection Moulding | M	0.105	0.006
5	Electronics	1	0.127	0.127	Printed circuit board assembly | N/A	N/A | N/A	16.461	1.235
6	Screw Bit Chuck	2	0.030	0.059	Stainless steel | L	Forging | L	4.281	0.321
7	Screw Bits	10	0.006	0.063	Stainless steel | L	Forging | L	4.571	0.343
8	Screws	6	0.001	0.004	Low carbon steel | L	Roll Forming | L	0.123	0.009
9	Plastic Gear Case	1	0.002	0.002	Polypropylene | M	Injection Moulding | M	0.142	0.011
10	Gears	6	<0.001	0.004	Polymethyl methacrylate | M	Injection Moulding | M	0.449	0.025
11	Storage Bit Holder	1	0.009	0.009	Polyvinylchloride | M	Injection Moulding | M	0.576	0.025
12	Trigger	1	0.002	0.002	Polypropylene | M	Injection Moulding | M	0.136	0.006
13	Metal Rod	1	0.006	0.006	Stainless steel | L	Extrusion | M	0.401	0.021

Key:

H – High Confidence (stated by the manufacturer, very clearly identifiable by visual inspection)

M – Medium Confidence (tested in the lab)

L – Low Confidence (other methods)

6.2 Embodied Energy and CO2 Footprint

The eco-audit tool has allowed to analyse the environmental impacts of the product. The results of this analysis can be seen below in Figure 5. Some assumptions were made about the product when creating this report. These were:

- The product's materials use no recycling content, as this was not mentioned anywhere in the product specification.
- The distance from Shenzhen (where the manufacturing plant is located) to London was assumed to be 19000 km by ship. (4)(5)
- The product was assumed to be used for an hour a year for 2 years. (6)
- It was said that the screwdriver is used in Europe.
- Landfill was said to be the product's destination.

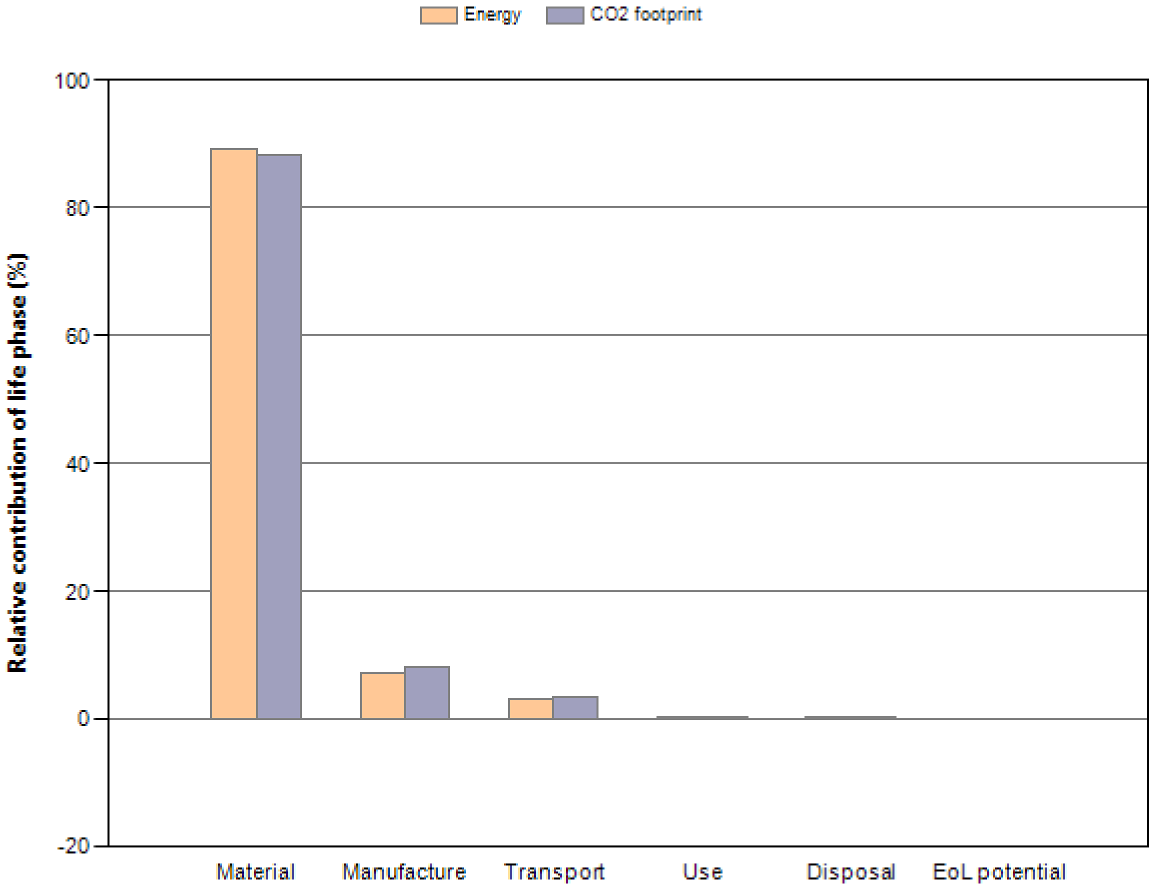

Figure 5 - A graph showing the respective contributions of different life phases.

It can be seen that the vast majority of the environmental impact comes from the material choices made, followed by the manufacturing processes. The use of the product has minimal impact. Additionally, it can also be noted that the transport and disposal of the product have minimal impacts on the environment. Hence, it should be prioritised to reduce the environmental impact of the materials and processes used by targeting the parts which have the highest impact in this regard. These are: the outer case, the handle grips, the screwdriver bits, and the screwdriver holder. Overall, while the uncertainty of the whole calculation is large, due to the significant difference between the most and least contributing parts it can be said that the parts with the most environmental effect have been identified correctly.

In Table 3 below, the total internal energy and total CO2 footprint after the whole lifecycle can be seen.

Table 3- total environmental impact of the product.

Phase	Energy (MJ)	Energy (%)	CO2 footprint (kg)	CO2 footprint (%)
Total (for first life)	**40.037**	**100**	**2.650**	**100**

6.3 Material and Manufacturing Analysis

As described in the Method section, various number of different approaches were taken to determine the materials used in the product. Each of these methods had a varying level of uncertainty associated with it. The top 4 most contributing parts (excluding electronics) were analysed below to understand the reasoning behind the material and manufacturing process choices.

6.3.1 Outer case

It was firmly established that the outer casing of the screwdriver is made from ABS plastic thanks to the clear indication by the manufacturer. The use of ABS is due to its high impact resistance and durability when compared to its low cost. It is perfectly justified and therefore will not be modified in the reverse-engineered version.

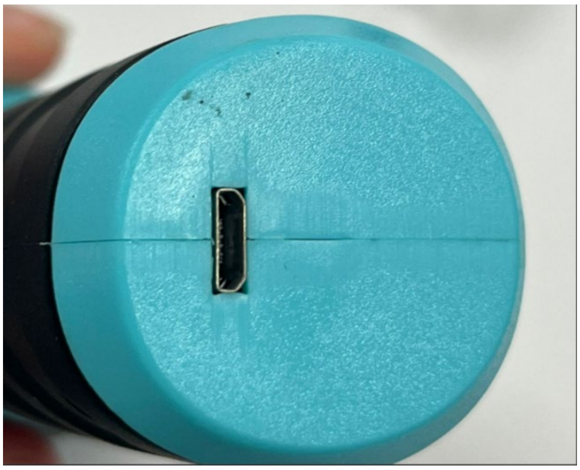

Figure 6 - the seam between two parts of the case

The manufacturing process was established to be most likely injection moulding. This can be supported by the fact that there is a clear seam in the middle of the casing, which indicates it was manufactured in 2 separate pieces and then joined together (see Figure 6). This is typical of injection moulded parts. Additionally, the inside of the casing has a much rougher finish, when compared to the outside of the casing. Again, this is something very typical of injection moulded parts. Therefore, this was established with high certainty as well.

Injection moulding was used in the case of the electric screwdriver because it is a highly efficient process that can mass-produce items with consistent quality, high accuracy, and low waste. Its use is very desirable in the case of the outer casing and therefore it will not be changed.

However, the finish of the outer casing feels rough and cheap due to its untreated nature. This is something that could be improved in the reverse-engineered version.

Figure 7 - the screwdriver bits

6.3.2 Screw bits and chucks

The screw bits and chucks were said to be made of Stainless Steel for the purposes of the level 2 database audit. However, during the group discussion, it was established that Chrome Vanadium Steel was in fact the material used for these bits. This is a material that is used widely for screw bits and is accepted to be the optimal solution. (7)

It was also suggested that forging is used to manufacture these bits. This is done as the bits need to be manufactured at a mass scale and this method allows for mass production at high rates. Forging also produces a hard and strong product, which is desirable in the case of a screwdriver bit.

6.3.3 Hand Grips

The hand grips were established to have been made from a silicone-based elastomer. This was used because of its high coefficient of friction and resistance to wear and tear. This makes it ideal for creating non-slip, soft, and long-lasting grip surfaces for products, which is the desirable quality here. However, it seems that the silicone does not cover enough surface area to produce a good user experience.

Figure 8 - how the overmould stays fixed to the case.

For this part, injection moulding was used alongside over-moulding the outer casing of the product. This was done to make sure that the silicone grip does not fall off the product and is firmly attached to the body.

6.4 Reverse Engineered Solution

The product's environmental impact can already be considered to be relatively low, therefore the approach for reverse engineering the product has taken a priority of redesigning it to match the client's brief while minimising any additional environmental impact.

Homer's Handymen has requested that the product must be designed to be and appear premium but at a low cost to the company, so that profits can be maximised. The following two proposals are aimed at fulfilling this request.

6.4.1 Outer Casing

The main issue with the outer casing was identified to be its poor appearance and feel. A solution to this would be to make the outer casing out of metal. This would make it feel much more premium and make the product more durable. However, there are many disadvantages to such an approach. Firstly, the tool would be likely to become much heavier than currently, reducing its ergonomic benefits. Secondly, such a solution would be much more expensive than the current solution due to the denser nature of metal. Thirdly, generally speaking, metals have a much higher embodied energy than plastics, making the product less sustainable. These reasons mean that making the casing out of metal is not a feasible solution.

Figure 9 - an ABS part electroless-plated with nickel.

However, a middle ground can be reached. A process called electroless plating can be used to create a thin and uniform layer of a metal, such as nickel, on top of the existing ABS part. This solution would be able to address all the problems mentioned about making the part purely out of metal. Although this process would still be more expensive, be heavier, and have a higher environmental impact than the current ABS solution, it would make the product stand out from other screwdrivers on the market and create a truly premium look and finish on a budget, see Figure 9. (8)

6.4.2 Hand Grips

An issue identified with the hand grips was that they were too small in size. The hand grips are manufactured using over-moulding over the ABS outer casing. Using this process it should be possible to extend the overmould to cover more of the handle of the screwdriver. This change would lead to better ergonomics at a low cost to the manufacturer. Such a change should improve the appeal of the product and hence fulfil the client's brief.

6.4.3 USB Cable

Currently, the screwdriver is shipped alongside a USB cable for charging. Most people already possess such a cable and it is likely that the cable included with the item is redundant. A possible way to decrease the product's environmental impact – by up to 5 MJ – could be to not include a charging cable in the box. Such a move is not uncommon, and several large multinational companies have already made use of such a scheme. (9) Such a move would also decrease manufacturing costs, which is something the client has requested.

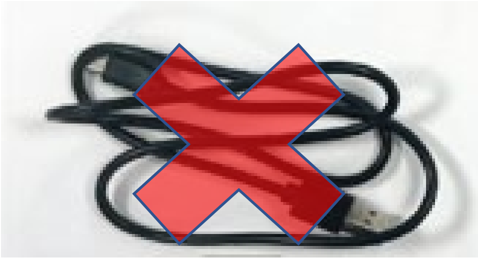

Figure 10 - the USB cable is redundant.

7 CONCLUSION

The Kiprim electric screwdriver has been improved upon the completion of a thorough reverse-engineering process. Firstly, the screwdriver was torn down into its primary components, a teardown board was created alongside a bill of materials. This bill consisted of the mass, material, manufacturing process, the total embodied energy, and the CO2 footprint of each part. Then after analysing the bill of materials, the parts with the most environmental impact were chosen for improvement. Namely, these were: the outer case, the handle grips, the screwdriver bits, and the screwdriver holder. During the improvement phase, priority was put on ensuring the client's brief is met while minimising any extra environmental impact.

The main improvement to the design was the addition of an electroless-plated layer on top of the ABS plastic in order to make the product seem more premium. Additionally, the size of the hand grips was suggested to be increased to improve usability. Lastly, in order to make the product more sustainable, it was suggested to remove the USB cable from the packaging.

8 Appendix

8.1 Product Teardown

Kiprim ES3 Electric Screwdriver

Target Customer: Amateur at Home Users

Retail Cost: £14.44

Est. Production Volume: 10,000 - 100,000

Manufactured In: Shenzhen, China

Figure 11 - the teardown board

8.2 Product Teardown Process Pictures

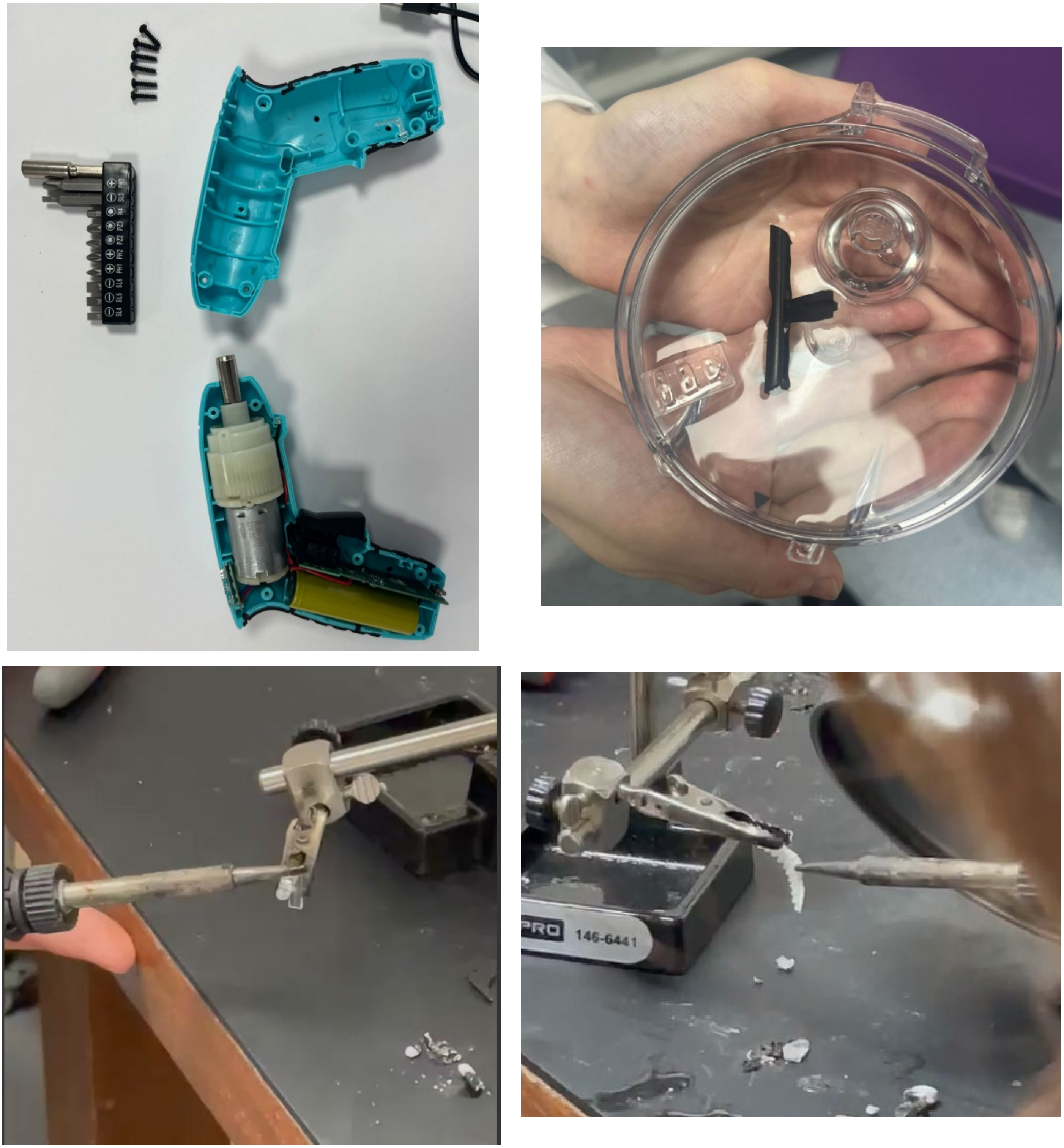

Figure 12 – Pictures from the teardown process

9 REFERENCES

1. Cheaytani R. Choosing the right electric screwdriver [Internet]. Buying Guides DirectIndustry. 2018 [cited 2023 Mar 21]. Available from: https://guide.directindustry.com/choosing-the-right-electric-screwdriver/

2. Small Mini Electric Screwdriver,Kiprim ES3 Cordless Screwdriver Tool with Rechargeable Battery,LED Front Light & Power Display Light for Home DIY : Amazon.co.uk: DIY & Tools [Internet]. [cited 2023 Mar 6]. Available from: https://www.amazon.co.uk/Electric-Screwdriver-Kiprim-ES3-Rechargeable/dp/B09M7ZY4ZM/ref=asc_df_B09M7ZY4ZM/?tag=googshopuk-21&linkCode=df0&hvadid=570447700924&hvpos=&hvnetw=g&hvrand=14851386893504150035&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9045903&hvtargid=pla-1647391241012&psc=1

3. Bosch Home and Garden Cordless Screwdriver IXO (5th generation, 3.6 V, in case) : Amazon.co.uk: Automotive [Internet]. [cited 2023 Mar 21]. Available from: https://www.amazon.co.uk/Bosch-Cordless-Screwdriver-Integrated-Lithium-Ion/dp/B0BCH64SVG/ref=sr_1_6?crid=2OZ279LROSXHY&keywords=electric%2Bscrewdriver&qid=1679394857&sprefix=electric%2Bsc%2Caps%2C122&sr=8-6&th=1

4. Shenzhen to London by Air freight, Cargo ship or Road - Fluent Cargo [Internet]. [cited 2023 Mar 22]. Available from: https://www.fluentcargo.com/routes/shenzhen-cn/london-gb

5. KIPRIM Trademark of SHENZHEN KEPURUI BUSINESS CO., LTD. - Registration Number 6113628 - Serial Number 88768393 :: Justia Trademarks [Internet]. [cited 2023 Mar 22]. Available from: http://trademarks.justia.com/887/68/kiprim-88768393.html

6. Do you own a drill? [Internet]. nesta. [cited 2023 Mar 6]. Available from: https://www.nesta.org.uk/blog/do-you-own-a-drill/

7. Jang HS, Liang SL, Chen ST. Development of Screwdriver Bit Steel with High Hardness and Torque Value.

8. shuobaocn. Common faults in ABS plastic plating [Internet]. ShuoBao Industrial Equipment. 2018 [cited 2023 Mar 22]. Available from: https://shuobaocn.com/common-faults-in-abs-plastic-plating/

9. No Charger in the Box? Everything You Need to Know About iPhone 14 Charging [Internet]. PCMag UK. 2022 [cited 2023 Mar 22]. Available from: https://uk.pcmag.com/mobile-phones/129523/no-charger-in-the-box-everything-you-need-to-know-about-charging-the-iphone-12