JBH Material Consultants
on behalf of
Tomaszewska Eco-Innovations Ltd.

TRIM ROUTER

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REVENG • DEI-PMat
Dyson School of Design Engineering

CONTENTS

Part A: Report

1. Technical Summary

This project focused on the reverse engineering of a brandless trim router in order to render it more suitable for sale by Tomaszewska Eco-Innovations (TEI). This involved further minimising the cost of the already inexpensive router, as well as considering ways to make it more eco-friendly.

In order to do this, the router was first comprehensively torn down into its constituent parts, and these were weighed and identified. This meant they could be written up into a full Bill of Materials, including values for their embodied energies and CO_2 emissions. This Bill was then used to select parts that it would be most worthwhile to modify (based on their emissions), and potential modifications were proposed.

The modifications can be summarised as one change to manufacturing process, involving the use of snap-fits where possible rather than relying on expensive and time-consuming mechanical fasteners, and one change to the product material, namely using a glass-reinforced polymer for the main body of the router instead of the steel with which it was supplied.

2. Introduction

As the title would suggest, this report was centred around the reverse engineering of an everyday product in order to gain a critical understanding of its make-up - specifically the materials and manufacturing processes that brought it into existence. The focus of the report, which was commissioned by TEI, was a brandless and extremely inexpensive trim router. The final goal of the report was to suggest modifications to be made to the product that would decrease product price as well as lessen the environmental impacts of the product. The main metrics that would be used for this were Embodied Energy and CO_2 emissions in the materials themselves and in production - and, of course, price.

3. Background

Trim routers (or laminate routers, palm routers) evolved, as their name suggests, to trim excess material from laminates and veneers after laminating (sticking layers together), for making two workpieces the same size, or for cutting mouldings, chamfers and rabbets.[1] They are particularly well suited to this, as they tend to be small and precise, and can easily be used to follow intricate shapes thanks to their pattern-following bits and attachments.

Figure 3.1: Three trim routers by Makita[8] (left), DeWalt[9] (centre) and Bosch[10] (right). These demonstrate three main uses of trim routers.

The three above routers (Figure 3.1), from well-respected brands, demonstrate each of these purposes. Both the left-hand and central routers above use similar construction, with a separate steel housing and a polymer top cap. The rightmost router, however, is made entirely from a polymer shell with overmoulded grip sections. This shows that there are many opportunities to use many different materials here. Although all three routers have metal stands, the clear polymer sections on two of them demonstrate that this, too is a viable material opportunity.

Most routers, including the focus of this project, are designed primarily for use on wood - equivalent tasks on metals can be accomplished by machining processes. The units themselves must also be precisely made, as they spin at around 26,000 RPM[2] (the focus of this report advertises 30,000 RPM).

Figure 3.2: The router and its components as they came out of the box

4. Method

Disassembly of this product was fairly straightforward where possible. There were, however, two subassemblies which were not possible to disassemble without access to a workshop. These were the motor rotor and the stator / motor cap assemblies, (see Figures 4.1 & 4.2 below). With the exception of these, disassembly was easy as the unit was held together entirely by mechanical fastenings: mostly self-tapping screws driven into plastic. Some had been fixed in place with thread locker, but even these were relatively easy to remove. Materials could then be identified, and processes examined. Plastics identification was made harder by the impossibility of accessing workshops this year, because this meant that burn tests were not a practical possibility.

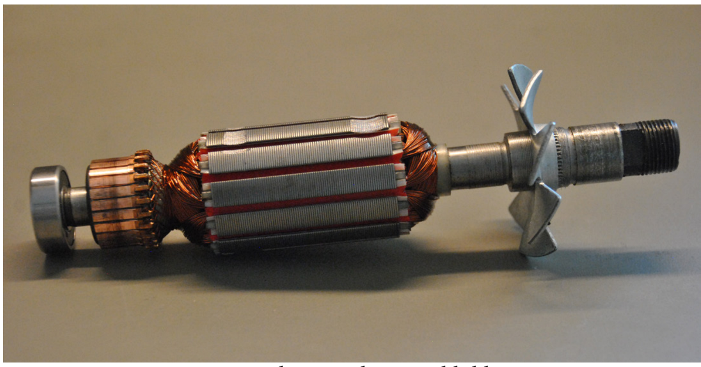

Figure 4.1: The non-disassemblable rotor

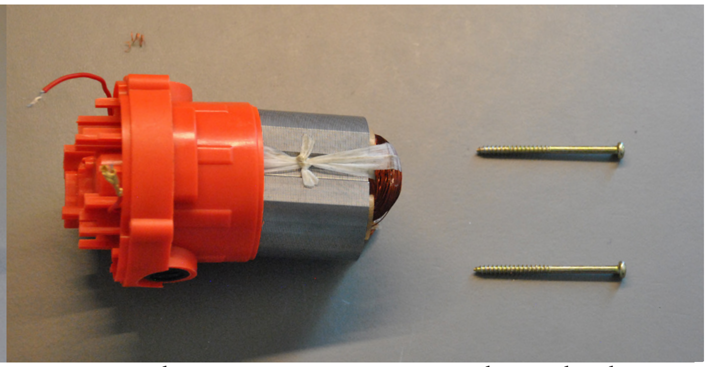

Figure 4.2: The motor's stator was permanently joined to the cap.

The actual process of disassembly was fairly simple, as the router is designed such that there was only ever one set of screws to remove at a time, before access to the next set. A full breakdown of the teardown process can be found in Appendix B: Teardown & Exploded View.

5. The Materials

In this section, materials were examined and written up into a Bill of Materials, before their various methods of manufacture were written up and their embodied energies and CO_2 footprints calculated. The router had

36 part types for a total 53 separable parts. The vast majority of these (23/36) contained steel in some form, and there were also several polymers (including fibre-reinforced ones) present.

5.1. Embodied Energy and CO_2 Footprint

Granta EduPack's Eco Audit tool was used (with Level 2 materials & processes) to construct a detailed bill of environmental impacts as the Bill of Materials was written up. This was based on the following assumptions:

- The product was made entirely from virgin materials
- The product made it's 22,000km journey[3] from China to the UK by sea
- A light goods vehicle (Amazon van) brought it the remaining 50km from depot to consumer
- Citing its extremely low price, the tool would be owned by an amateur DIY'er who would not use it on a regular basis, and would not have a need to dispose of it for a long time - end-of-life effects were not taken into account.
- This DIY'er uses the product for one hour per day on each of four days per year, for at least 20 years.

It is worth noting that several materials were not explicitly included in the Eco Audit as they were not available on Granta EduPack. These were the graphite brushes (graphite is not a Level 2 material) the bearings (their masses were included with other parts) and the crimp connector - which was deemed small enough not to include, as it did not fit any of Granta's categories.

5.2. Bill of Materials

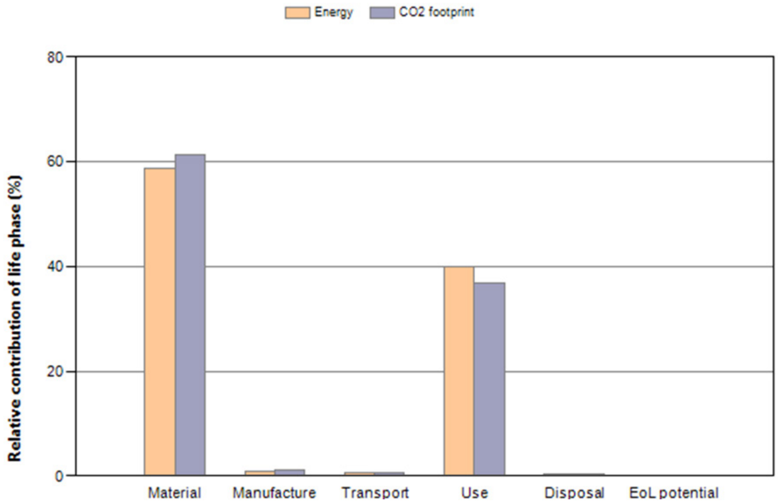

Figure 5.1: An footprints plot for the trim router (from Granta EduPack)

During the teardown process, a detailed Bill of Materials was produced. The full version is available in Appendix A, but the below is a summary which, for brevity, excludes all screws (as they are a very small part of the whole) and does not give detailed comment on parts. The assumptions outlined in 5.1. applied in the production of this Bill, as did the omissions of parts not included in Granta's EduPack.

Table 5.1: An excerpt of the full Bill of Materials, which can be found in the appendices.

Nº	Part	Quantity	Weight /g	Manufacturing Method	Total Energy /MJ	Total CO_2 /kg
1	Brush cap	2	<1	Injection moulding	0.221	0.01
2	Brush	6	5	Extrusion	N/A	N/A
3	Base	1	104	Injection moulding		
3.1	Base - Grip	1		Over-moulding lines visible	12.9	0.63
4	Thumb screw	1	13	Thread rolling & overmoulding		
5	M5 Nut	1		Thread rolling & others	1.1	0.3761
7	Base plate	1	22	Injection moulding	1.13	0.083
9	Top cap	1	41	Injection moulding	2.71	0.131

11	Cable retainer	1	<1	Injection moulding	6.79	0.357
12	Crimp connector	1	<1	Stamped, pushed into sleeve	0.102	0.0035
13	Switch	1	8	Various	0.091	0.0086
14	Flex Grommet	1	8	Injection moulding	1.27	0.069
15	Flex	1	151	Various	0.64	0.0308
16	Motor stator	1	410	Various	14	1
17	Inner housing	1		Injection moulding	390	22
18	Main Housing	1	230	Cast & turned	6.57	0.345
19	Collet Nut	1	11	Machining	9.8	0.73
20	Collet	1	5	Machining	0.417	0.0303
21	Fan	1	92	Stamping	0.302	0.0221
22	Rotor	1	275	Various	3.93	0.29
23	Bearing	2		Various	290	16
24	M6 Knob	2	21			
25	M6 Adjuster	1	12	Thread rolling & overmoulding	1.39	0.099
26	Adjuster slider	1	12	Cast - ejector pins visible	2.44	0.1584
27	Crude bearing	1	4	Extruded then machined	0.17	0.0125
30	U-plate	1	3	Rolled then punched	0.127	0.0094
31	Guide Slider 1	1	25	Cast - ejector pins visible	5.09	0.328
34	Edge guide	1	86	Punched then folded	3.67	0.265
35	Guide Slider 2	1	46	Punched then folded	2.02	0.149

5.3.Critical Components, their Materials, Manufacture and Footprints

As mentioned above, materials identification was more challenging this year due to the difficulty in accessing workshops. However, there were still some processes it was possible to follow. The materials found to have the highest energy and carbon footprints are presented below, because reducing the impacts of these would have the biggest overall impact on the emissions of the product.

5.3.1. Motor Stator & Rotor

Both the stator and rotor were manufactured in similar ways, and are made of similar materials, so they are grouped here. Together, they account for 89.6% of the overall embodied energy and 86.6% of overall CO_2 footprint. The picture this paints is less dire when we consider that they make up almost 40% of the overall weight of the product - but it is still a large amount of energy and CO_2, and highlights the importance of reducing electrical waste.

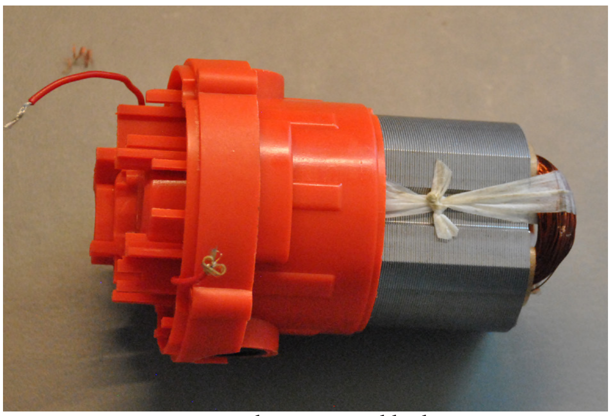

Figure 5.2: The stator and body cap.

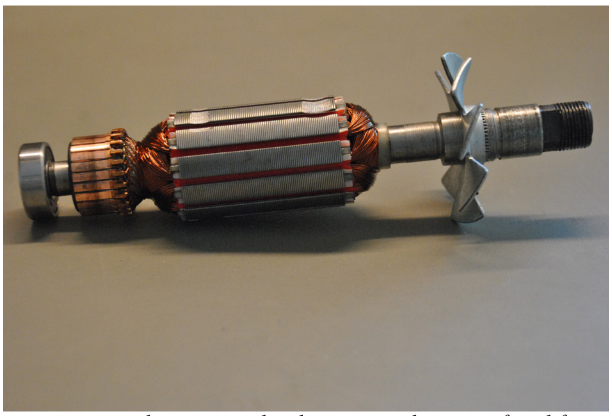

Figure 5.3: The rotor with a bearing and a press-fitted fan.

The router uses an 800W induction motor consisting of an outer, static, stator and an inner rotor connected to a copper commutator ring interfacing with two graphite brushes.[4] They were manufactured by laminating stamped steel sheets together into armatures, before winding copper wire through these and pressing them onto their shafts. Unfortunately, this meant neither could be easily disassembled, so the journey for these ended here. Nearly 90% of the product's emissions were locked into these components but, as it was assumed that they were pre-manufactured, there was little that could be done here.

5.3.2. Flex & Over-moulded Plug

Accounting for approximately 2% of each of embodied energy and CO_2, the flex and its plug were the next big components. Again, however, these were assumed to be pre-manufactured and had to be left aside.

5.3.3. Polycarbonate Stand & Base

At 7.6% of the weight and 2.1% and 1.7% of embodied energy and CO_2 footprint respectively, the next big contributors here were the polycarbonate parts: the clear, injection-moulded stand and its replaceable base (they were injection moulded as both an injection nipple and ejector pins are visible). They serve an essential role in keeping the axis of rotation of the router bit perpendicular to the work, and in setting the depth of cut. As in Figure 5.4, the over-moulded soft plastic (possibly a thermosetting elastomer of some sort) provides a comfortable and safe grip, but is very hard to separate from the main polycarbonate body at the end of the product's life. However, two excellent features were that the base of the stand could be replaced should it become worn, lengthening the life of the product as a whole (Figure 5.5), and that this polycarbonate part was an environmental improvement on steel, which is used in comparable products.

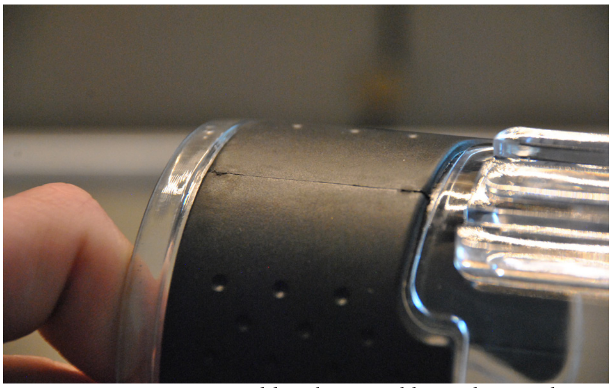

Figure 5.4: Overmoulding lines visible on the stand.

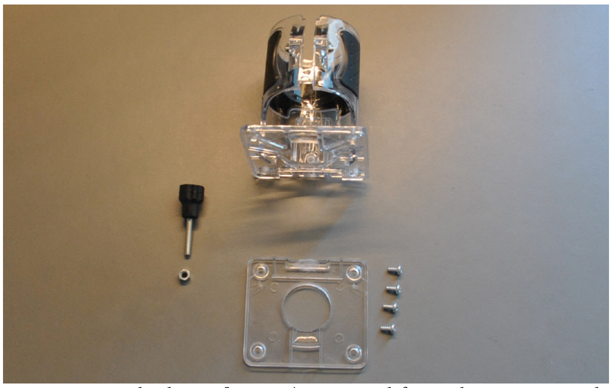

Figure 5.5: The base (bottom) removed from the main stand.

The embodied energy and CO_2 footprint of these parts are split as follows:

	Production	Transport	Total
Embodied Energy /MJ	13.3	2.31	15.61
CO_2 Footprint /kg	0.59	0.171	0.761

5.3.4. Main Housing

Accounting for 13.9% of the overall product weight and making up 1.3% of its embodied energy and 1.7% of carbon footprint, the next largest contributor to the emissions of this product was the main, steel housing itself. It was cast then turned to size on a lathe, as can be seen by the characteristic grey surface left by casting showing through the spiral grooves left by a lathe (see Figures 5.6 & 5.7). It was used to keep the motor together, holding the bit-end of the rotor, as well as providing an accurate surface for the stand to clamp to.

The embodied energy and CO_2 footprints are as follows:

	Production	Transport	Total
Embodied Energy /MJ	7.1	2.7	9.8
CO_2 Footprint /kg	0.53	0.2	0.73

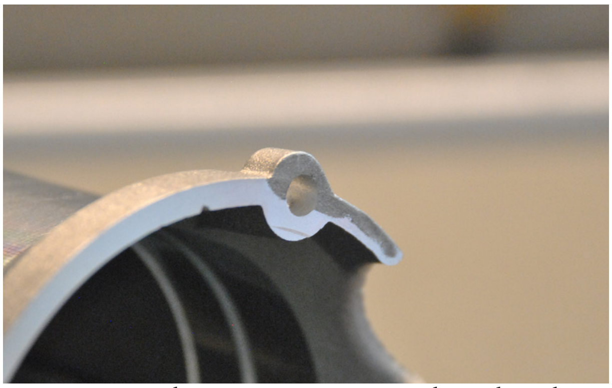
Figure 5.6: Characteristic cast texture shows through.


Figure 5.7: Imperfections in the cast leave small holes.

5.3.5. Top Cap & Inner Housing

Both of these parts were helpfully labelled PA6-GF30 (Figure 5.8), meaning they were made from a polyamide (PA6) reinforced with 30% glass fibres (GF30). They were joined using self-tapping screws, and the inner housing had a locator brim to keep the top cap in place (Figure 5.9). At 4.6% of the product weight, together they represented 1.8% of embodied energy and 1.6% CO_2 emissions. They had distinctive reinforcing ribs on the inside which suggests injection moulding, but this could not be confirmed as no ejector pin marks were visible.

Figure 5.8: The convenient labelling on the top cap.

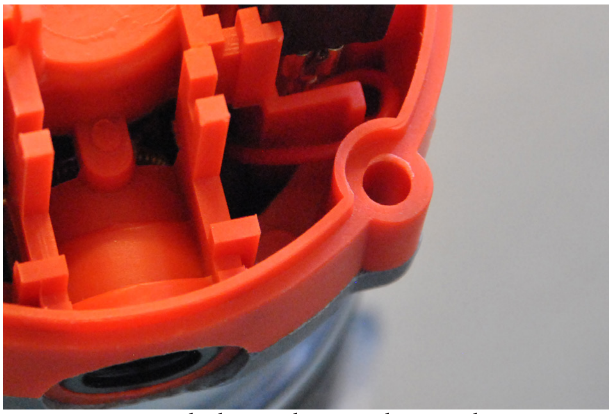
Figure 5.9: The locator brim on the inner housing.

5.4. Proposed Modifications

For proposed modifications to the product to improve its eco-credentials (for TEI), the main foci were on 5.3.4. above and on the assembly methods for this product, because 5.3.1. and 5.3.2. were deemed pre-manufactured subassemblies and so could not be improved here, and because the polycarbonate and PA6-GF30 used in 5.3.3. and 5.3.5. are extremely good materials for the job, so changing them may have been counterproductive in terms of emissions or product lifespan - which were important considerations for TEI.

5.4.1. Main Housing

The main, steel housing of this router was found to contribute 9.8 MJ and 0.73 $kgCO_2$ to the overall emissions. It was found to be relatively easy to reduce this (reducing the overall emissions) by taking inspiration from the suspiciously similar Makita 3707 router (it is likely that the subject of this report was an attempted clone of the 3707), which appears to use the same material for the main housing as for the top cap (Figure 5.10). In the case of this router, that material was PA6-GF30. The practicality of this modification was investigated, and, in order to do so, a volume-equivalence assumption was made - i.e. the *volume* of the new part (not its mass) would be the same as that of the part it replaced. This is because PA6-GF30 is less dense than steel so using a mass equivalence would result in an over-engineered component.

First, the volume of the original steel housing was calculated:

$$v = m / \rho \quad \bullet \quad m = 230\ g \quad \bullet \quad \rho_{steel} = 7.75\ g/cm^3\ ^{(5)}$$

$$\therefore v = 230 / 7.75 = \underline{29.7 cm^3}$$

Next, the required mass of PA6-GF30 to take up this volume was found:

$$m = v\rho \quad \bullet \quad \rho_{PA6\text{-}GF30} = 1.36\ g/cm^3\ ^{(6)}$$

$$m = 29.7 * 1.36 = \underline{40.4\ g}$$

Figure 5.10: The Makita 3707[11] has a main housing made of the same material as the cap.

With this information, the new embodied energy and CO_2 footprint could be calculated using Granta EduPack:

	Production	Transport	Total
Embodied Energy /MJ	5.8	0.88	6.68
CO_2 Footprint /kg	0.28	0.066	0.346

This represents a big saving - the original values, quoted in 5.3.4., were 9.8 MJ and 0.73 kgCO_2 - so this simple change represented a saving of 3.12 MJ and 0.384 kgCO_2. This meant a 32% drop in energy used and a 53% decrease in CO_2 produced, which fulfils the criteria supplied by TEI for an eco-friendly solution. The cost of this change, however, was slightly reduced durability. However, as Makita, a highly respected tool manufacturer, finds this a sacrifice worth making (and the use case for this product was taken to be occasional use from a DIY'er) this did not seem to be an issue.

5.4.2. Assembly

A second way of improving this product (specifically to decrease its price) was studied. This had to do with assembly processes and methods, rather than the components from which parts were made. The whole body of the router was assembled with mechanical fastenings, namely screws and bolts. For some parts, this provided essential adjustment - for example it was a thumbscrew and nut that provided the clamping force to hold the base to the main router body. In other areas, user adjustment and disassembly are not needed, so it may have been advantageous to use interference fits instead of screws.

Interference (specifically 'snap') fits were found to have numerous advantages over mechanical fasteners. The most important among these were:[7]

- Easier assembly in large production volumes
- Lower unit costs - fasteners do not have to be bought or inserted and tightened - and cheaper implementation
- Fewer moving parts reduce product complexity

However, they do have some drawbacks:

- Can be difficult to take apart - as this product was considered to be used in DIY, this did not seem an issue.
- They are perceived as cheap - the product as a whole was cheap, so again, this was not an issue.
- If snaps are broken, the whole part must be replaced - again, as disassembly was likely not part of this item's use case, the likelihood of a broken snap is low.

6. Conclusion

This study has taken a brandless, inexpensive trim router and suggested modifications to further decrease its price and lessen its environmental impacts. These changes have brought the product within the manufacturing remit of Tomaszewska Eco-Innovations, a prestigious and well-known brand specialising in eco-friendly products.
The router was first torn down to its constituent parts and a full Bill of Materials was created. This Bill included information about the physical properties of individual components, as well as their embodied energies and CO_2 footprints. This information was used to select the most environmentally damaging components of the router, which turned out to be the motor and stator, the flex with its over-moulded plug, the router's polycarbonate stand, and the steel housing. A modification was suggested for the fourth of these, as the first two were considered pre-manufactured and the third was found to be very fit for purpose and already an environmental improvement in the steel usually used in comparable products. The modification saw the material of the main housing changed from steel to the glass-fibre reinforced polymer PA6-GF30, which was used elsewhere on the product.

The second suggested modification had more to do with assembly techniques, although it would necessarily affect the components manufactured. JBH Material Consultants suggested using snap-fitting components where possible, as these would make for a considerably cheaper assembly process than the screws currently used and, as the product was considered one that might be used by an amateur DIY'er, the slightly increased complexity of disassembly was not deemed to be a problem.

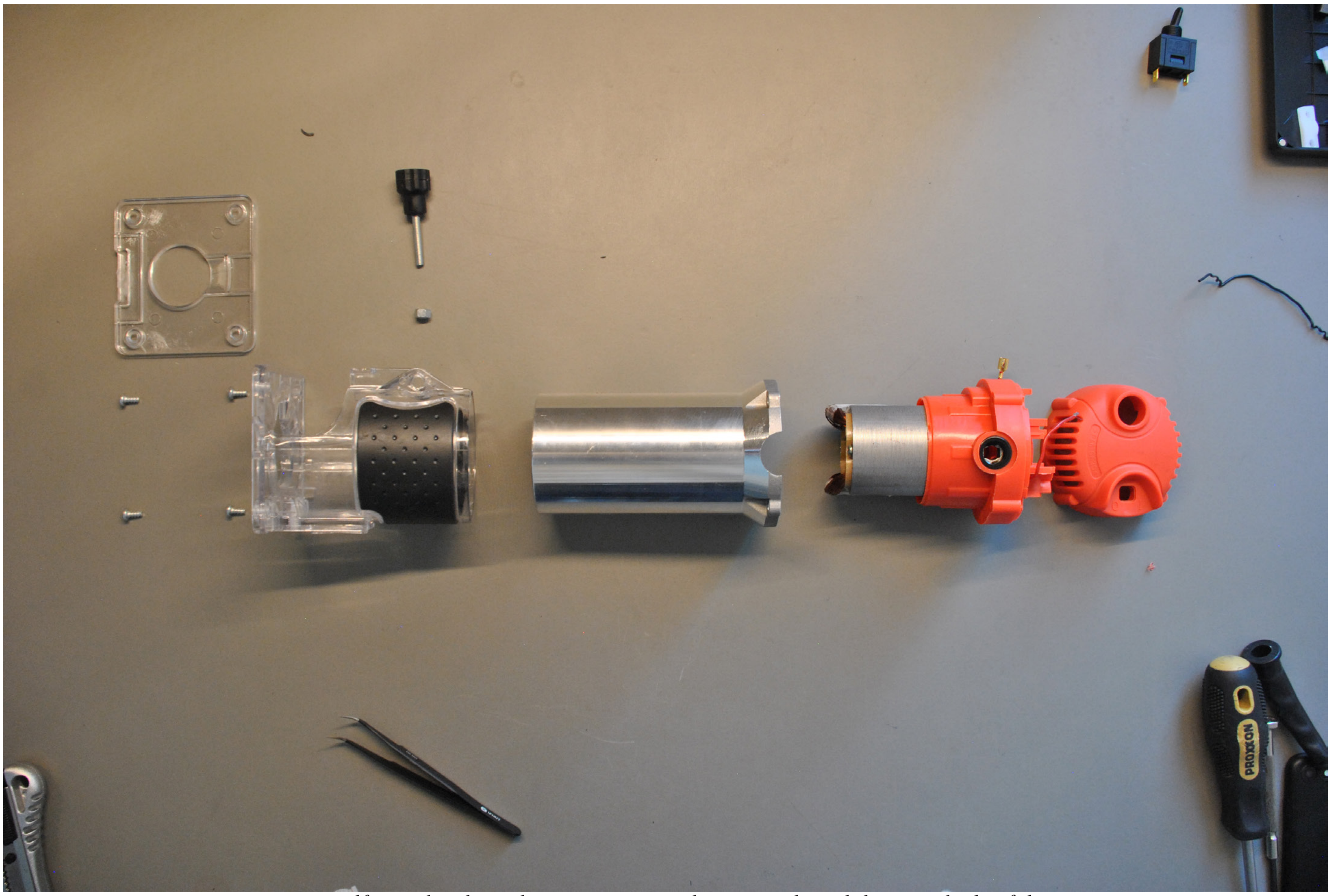

Figure 6.1: Half-completed teardown in progress, showing tools and the main body of the router.

Part B: Appendices

Appendix A: Bill of Materials

What follows is the Bill of Materials seen above (in 5.2.) with more detail on each component. The leftmost column of numbers refers to the part number to be found in Appendix B: Teardown & Exploded View. The name of each part, its function and other comments, the quantity present and its mass are all shown, as well as a comment on how it was identified and a confidence rating in the material and manufacturing method identification.

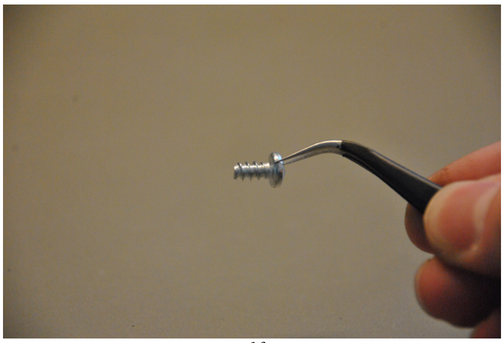

Figure B.1: A self-tapping screw.

A note on fixings:

There were many screws of several different types and lengths holding this router together (good to see - better than glue!), but, as they are all made from steel with some form of galvanic coating, they have been grouped for the weighing stage: this improves accuracy of the measurement, as each individual screw weighs a mere fraction of a gram.

The table is included overleaf.

Number	Part	Description	Material	Quantity	(Volume)	(Density)	Weight	Total Weight	ID Comment	Confidence	Manufacturing Method	Confidence	Materials	Processes	Total Energy	Materials	Processes	CO2 Total
1	Brush cap	Holds motor brushes	ABS	2			<1g	<1	Sinks in water, black and shiny. Feels like lego.	80%	Injection moulding	60%	0.18	0.041	0.221	0.0069	0.0031	0.01
2	Brush	(Only 2 shown)	Graphite, steel & copper	6			1	5	Writes like a pencil	100%	Extrusion	50%						0
3	Base	Device stand	Polycarbonate	1					Clear, brittle	70%	Injection moulding	95%						
3.1	Base - Grip	Overmoulded	Maybe a TPE - 'Thermoplastic Elastomer'	1			104	104	Most common material for overmolding	75%	Overmoulding lines visible	90%	11	1.9	12.9	0.49	0.14	0.63
4	Thumb screw	Height adjustment	Galvanised medium-carbon steel with ABS	1					Pugent when heated, by analogy with bolts	80%	Thread rolling & overmoulding	85%						
5	M5 Nut	Used with (4)	Galvanised medium-carbon steel	1			13	13	By analogy with other nuts & bolts	95%	Thread rolling & others	90%	0.42	0.68	1.1	0.371	0.0051	0.3761
6	Screws	10mm Self-Tappers	Galvanised medium-carbon steel	4			(All screws)	30	By analogy with other screws	95%	Thread rolling & others	85%	0.97	0.16	1.13	0.071	0.012	0.083
7	Base plate	Replaceable if worn	Polycarbonate	1			22	22	Clear, brittle	70%	Injection moulding	95%	2.3	0.41	2.71	0.1	0.031	0.131
8	Screws	Attach top cover	Yellow zinc coated steel	4			See (6)	See (6)	By analogy with Goldscrew	85%	Thread rolling & others	85%	See (6)					
9	Top cap	Covers electrics	PA6-GF30 (Polyamide, 30% glass)	1			41	41	Helpfully written on it	100%	Injection moulding	80%	5.9	0.89	6.79	0.29	0.067	0.357
10	Screws	Hold cable retainer	Galvanised medium-carbon steel	2			See (6)		By analogy with other screws	95%	Thread rolling & others	85%	See (6)					
11	Cable retainer	Stops flex from being pulled out	HDPE	1			<1	<1	Translucent, scratches, cuts easily	60%	Injection moulding	90%	0.08	0.022	0.102	0.0019	0.0016	0.0035
12	Crimp connector	Connects non-switched wires	Tin-plated brass & nylon	1			<1	<1	Found tech specs online	90%	Stamped, push-fit into sleeve	90%	0.091		0.091	0.0086		0.0086
13	Switch		Nylon PA66	1			8	8	By analogy with other switches	75%	Various	-	1.1	0.17	1.27	0.056	0.013	0.069
14	Flex Grommet	Protects flex entering housing	PVC	1			8	8	By analogy with other cable grommets	80%	Injection moulding	85%	0.52	0.12	0.64	0.022	0.0088	0.0308
15	Flex	With overmoulded plug	Mixed materials	1			151	151	Metals, plastics & ceramics (in fuse) are presen	100%	Various	-	14		14	1		1
16	Motor stator		Steel, copper	1					Copper windings. Standard steel laminate core.	95%	Various	-	3.90E+02		390	2.20E+01		22
17	Inner housing		PA6-GF30 (Polyamide, 30% glass)	1			410	410	Helpfully written on it	100%	Injection moulding	80%	5.7	0.87	6.57	0.28	0.065	0.345
18	Main Housing		Steel	1			230	230	Does not scratch (as aluminium would)	95%	Cast & turned	95%	7.1	2.7	9.8	0.53	0.2	0.73
19	Collet Nut		Steel	1			11	11	By analogy with other nuts & bolts	95%	Machining	55%	0.36	0.057	0.417	0.026	0.0043	0.0303
20	Collet		Steel	1			5	5	By analogy with nuts & bolts	95%	Machining	55%	0.26	0.042	0.302	0.019	0.0031	0.0221
21	Fan		Steel (stamped)	1	1.2E-05	7800	92	92	Small patches of rust forming	90%	Stamping	90%	3	0.93	3.93	0.22	0.07	0.29
22	Rotor		Steel, copper	1					Copper windings. Standard steel laminate core.	95%	Various	-						
23	Bearing	Only 1 shown	Steel	2			275	275	Not ceramic, common bearing type.	95%	Various	-	2.90E+02		290	1.60E+01		16
24	M6 Knob		Galvanised medium-carbon steel with ABS	2			11	21	Pugent when heated, by analogy with bolts	80%	Thread rolling & overmoulding	80%						
25	M6 Adjuster		Galvanised medium-carbon steel with ABS	1			12	12	Pugent when heated, by analogy with bolts	80%	Thread rolling & overmoulding	80%	1.2	0.19	1.39	0.085	0.014	9.90E-02
26	Adjuster slider		Anodised aluminium	1			12	12	Low density, but unusual surface colour	50%	Cast - ejector pins visible	95%	2.3	0.14	2.44	0.15	0.0084	0.1584
27	Crude bearing		Galvanised steel	1			4	4	By analogy with other galvanised parts	70%	Extruded then machined	60%	0.13	0.04	0.17	0.0095	0.003	0.0125
28	Screw	Bearing holder	Galvanised medium-carbon steel	1			See (6)	See (6)	By analogy with other screws	95%	Thread rolling & others	85%	See (6)					
29	Screw	U-plate holder	Yellow zinc coated steel	1			See (6)	See (6)	By analogy with Goldscrew	85%	Thread rolling & others	85%	See (6)					
30	U-plate		Galvanised steel	1			3	3	By analogy with other galvanised parts	95%	Rolled then punched	70%	0.097	0.03	0.127	0.0071	0.0023	0.0094
31	Guide Slider 1		Anodised aluminium	1			25	25	Low density, but unusual surface colour	50%	Cast - ejector pins visible	95%	4.8	0.29	5.09	0.31	0.018	0.328
32	M6 Carriage bolt		Blacked medium-carbon steel	1			See (6)	See (6)	By analogy with other nuts & bolts	95%	Thread rolling & others	85%	See (6)					
33	M6 wing nut		Blacked medium-carbon steel	1			See (6)	See (6)	By analogy with other nuts & bolts	95%	Casting, Machining	50%	See (6)					
34	Edge guide		Galvanised steel	1			86	86	By analogy with other galvanised parts	95%	Punched then folded	90%	2.8	0.87	3.67	0.2	0.065	0.265
35	Guide Slider 2		Galvanised steel	1			46	46	By analogy with other galvanised parts	95%	Punched then folded	90%	1.5	0.52	2.02	0.11	0.039	0.149
(X)	Spanners	(Not shown)	Galvanised steel	2			23	46	By analogy with other galvanised parts	95%	Punched	95%	1.5	0.46	1.96	0.11	0.036	0.146

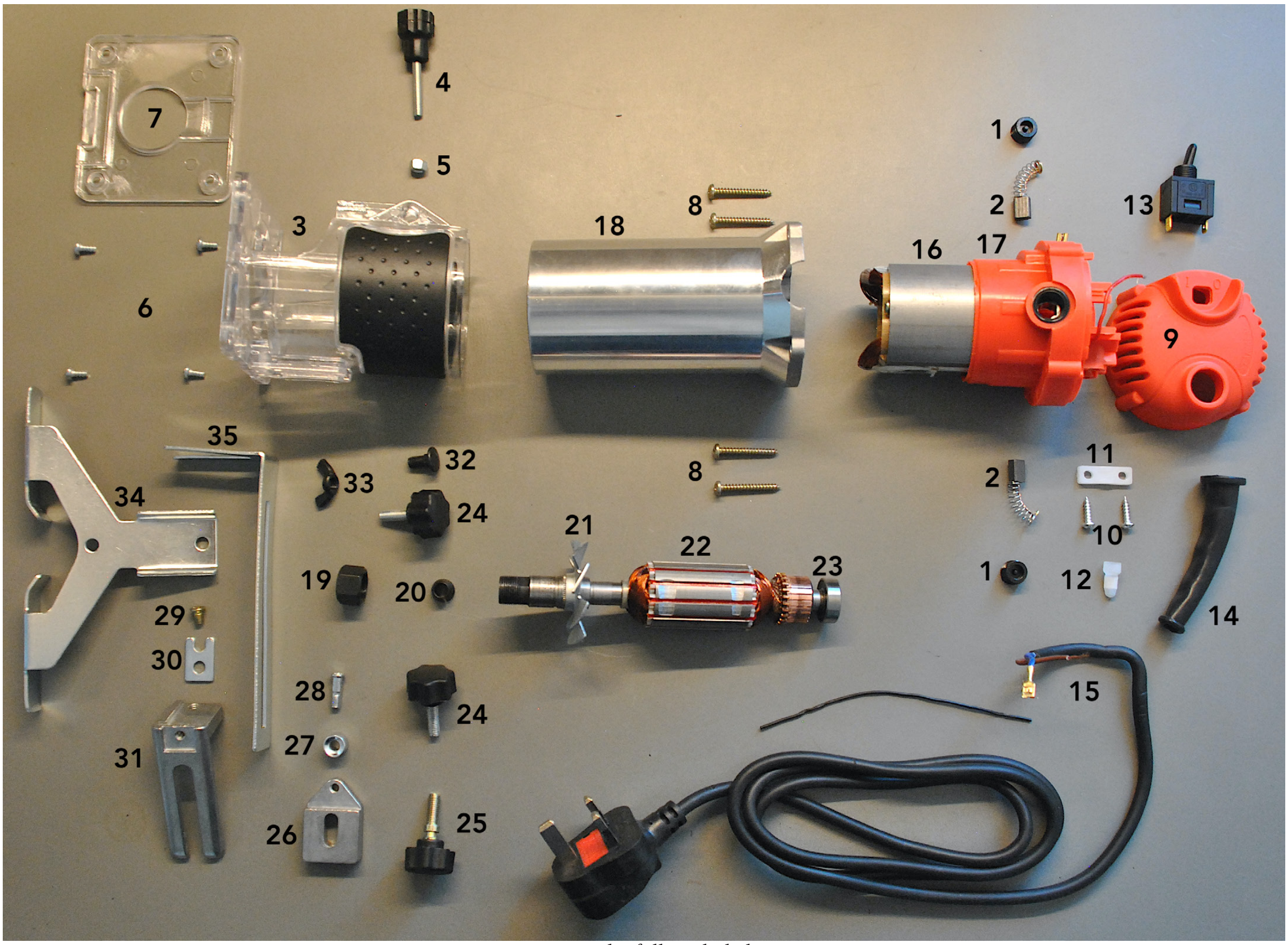

Figure B.2: The full exploded view.

The above image shows an exploded view of the trim router after the teardown. The parts are numbered in the order that they were removed, and correspond to the numbers on the Bill of Materials in Appendix A, where a complete list of all the parts above can be found. The below focuses on the process and steps involved in teardown.

1. The Brushes

The first and easiest things to remove were the shiny black brush caps and the carbon brushes underneath.

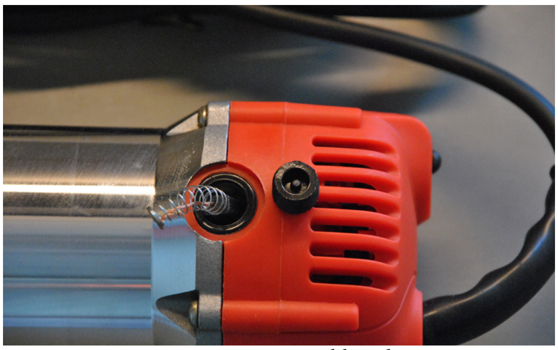

Figure B.3: A removed brush cap.

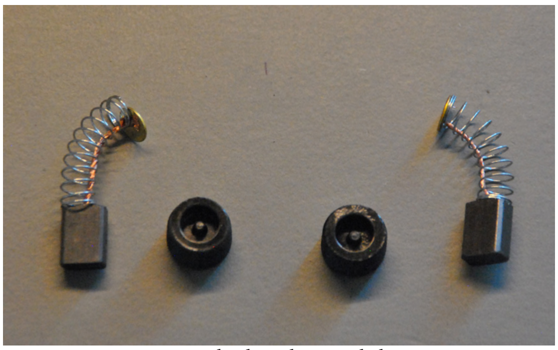

Figure B.4: The brushes and their caps.

2. The Stand

The stand came apart fairly easily, being held together only by four screws and a thumbscrew. The black grip had been over-moulded over the injection-moulded stand - this was shown by the slight flash on the grip.

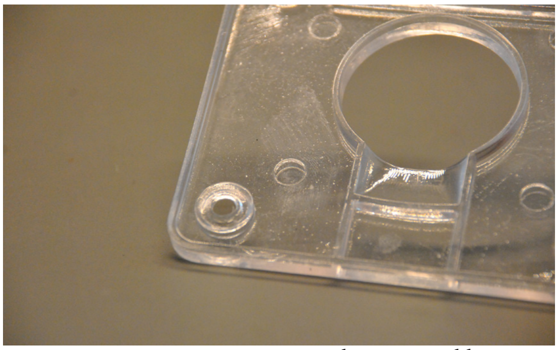
Figure B.5: Ejector pin marks were visible.

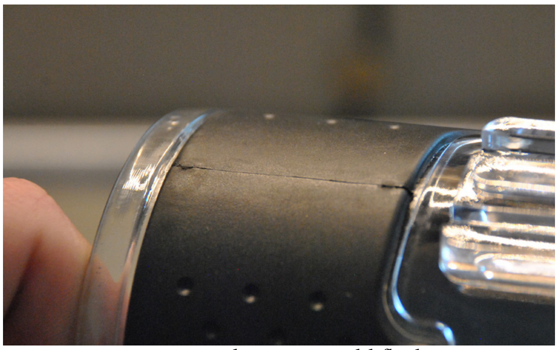
Figure B.6: The over-mould flashing

3. Body cap
The next part to be removed was the body cap. This allowed the flex, flex protector, cable retainer and switch to be removed.

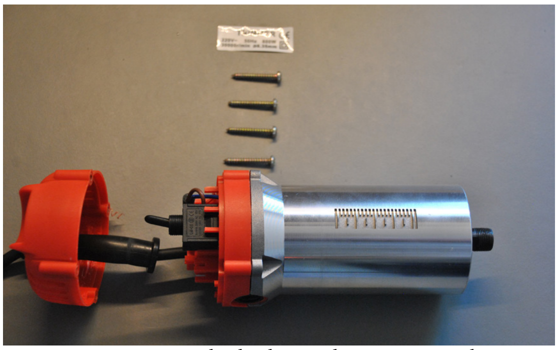
Figure B.7: The body cap being removed.

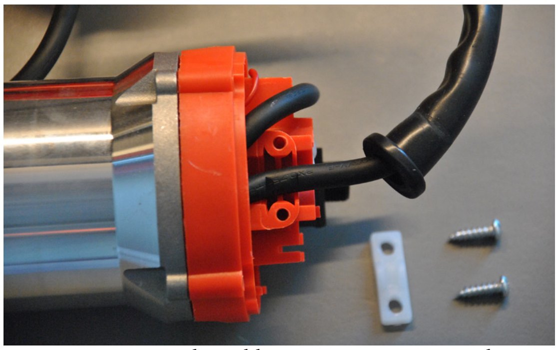
Figure B.8: The cable retainer was removed.

4. Electrics
The electrics of this router were extremely simple, consisting of a switch and a crimp connector.

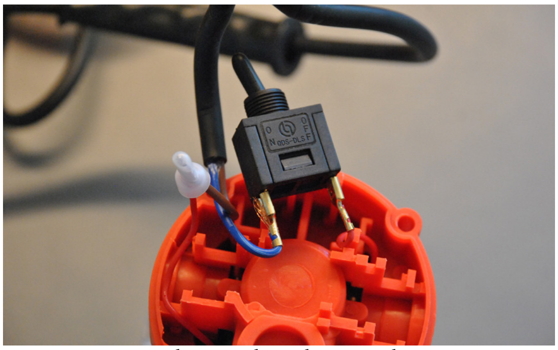
Figure B.9: The switch and crimped connection.

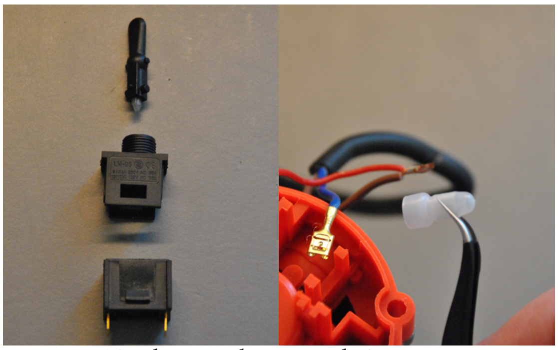
Figure B.10: The torn-down switch & crimp connector.

5. Stator
The stator and the motor cap weren't possible to separate without further tools.

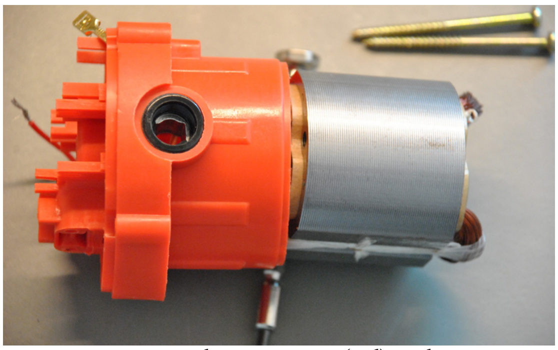
Figure B.11: The motor cap (red) and stator.

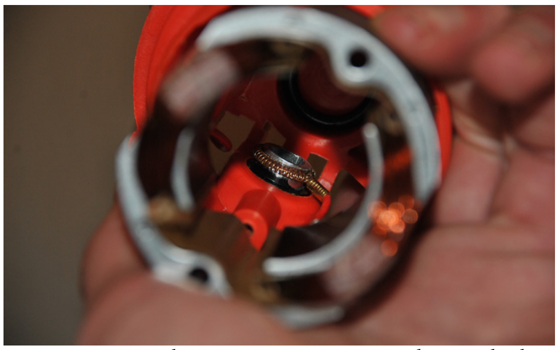
Figure B.12: The stator was permanently attached.

6. Rotor & Housing
The rotor was press-fitted into a bearing at the base of the housing. Without a bearing puller, this was extremely difficult (but possible) to remove. Particularly interesting to see were the balance grindings on the armature itself, used to balance the coil by removing material until it spins smoothly and does not vibrate.

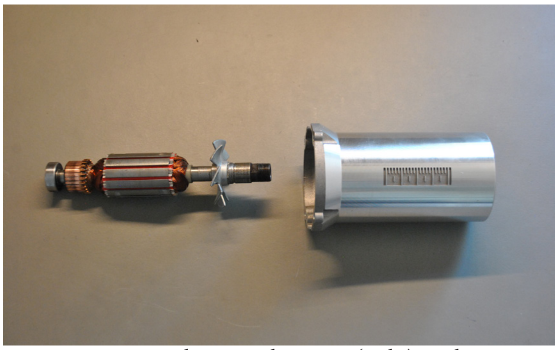

Figure B.13: The main housing (right) and rotor.

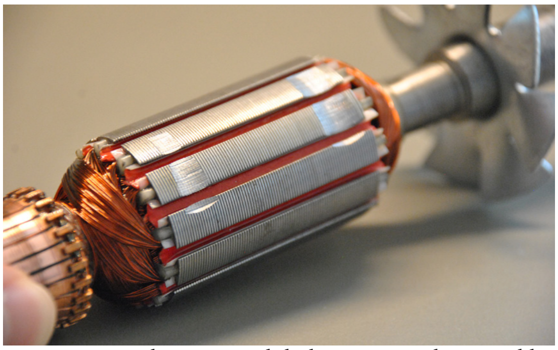

Figure B.14: The rotor with balancing grindings visible.

Aside from the various guides supplied with the router, this brought the teardown to an end. The guides were very straightforward to dismantle and as such do not merit inclusion here. They are, however, of course included in the Bill of Materials.

Appendix C: References

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Figures not cited above were taken or created by me.