IMPERIAL COLLEGE LONDON
DEPARTMENT OF MATERIALS

MATE50003 ENGINEERING PRACTICE

Preliminary Report

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Executive Summary

In this report, a FADAKWALT 8212A Cordless Drill Driver has been modelled using the CAD software SolidWorks, key functions and components have been identified and a characterisation plan has been produced to explain further questions about the product. The drill is designed for small to mid sized projects for at-home users. The keyless chuck, removable battery, wireless capabilities and adjustable torque lead to ease of use for people without a technical background. Whilst the bright colours play into the aesthetics of at-home use. The key functions were identified to be the ergonomic casing, the power system and the rotary system. The key components for characterisation were then identified to be the casing, the gearbox and the chuck. These are all vital for the functionality of the drill but are also believed to be designed by the company (as opposed to bought in) allowing for design freedom in the materials selection stage. To better understand the materials used in the product and suggest improvements, further characterisation must be utilised so a characterisation plan has been produced for further work. From company documentation, the materials used in the casing was a 30% glass fibre reinforced polyamide 6 (PA6-GF30) which is visible as the green matte sections on the design and also a thermoplastic elastomer (TPE), visible as the black matte sections on the design. FTIR was chosen as the primary characterisation technique to identify the thermoplastic elastomer chemistry for further analysis. SEM/EDX has also picked as a technique which will expose information about the dispersion of the glass fibres within the matrix. It is only known that the gearbox and chuck are made from steel. The hardness of both these components is vital to the lifetime expected from the drill so both will undergo a hardness test. Understanding the microstructure and composition of the gears is of high importance as these can lead to fatigue failure. We have therefore decided to employ a range of characterisation techniques such as LOM, SEM/EDX and XRD for the gears. This will allow us to draw conclusions about the composition of the metal as well as the processing methods used to manufacture them to suggest improvements. The predicted expenditure of this characterisation was £3425 leaving room for adjustments in the plan.

1 Description of item and identification of key functions

The FADAKWALT 8212A Cordless Drill Driver, containing a 12V Li-ion battery and a maximum power of 600W, is tailored for a diverse array of drilling and driving tasks, offering an impressive torque of 180-inch pounds. This tool, marked by its distinctive matte green casing and rubber-like grip, combines functionality with aesthetic appeal, providing a sleek look while ensuring comfort and control. The matte plastic chuck and clutch contribute to the device's lightweight yet durable design. Despite its price range on Amazon, varying from £20 to £86, the FADAKWALT 8212A exudes a mid-range quality feel that belies its cost, it is lightweight and has a relatively cheap feel to it. It is reasonable to conclude that this product was designed for at-home use for DIY projects where a heavy duty drill it not required. It stands out for its ergonomic design and balanced weight distribution, which enhance usability and minimize fatigue during extended use. Assembly-wise, the drill utilizes screws for a secure fit, alongside a cleverly designed clip at the base of the handle to accommodate the battery pack, indicating a design optimized for reliability and ease of maintenance. This thoughtful approach to assembly not only ensures the drill's robustness but also its repairability, with the potential for easy disassembly when repairs or battery replacements are needed, thereby extending the product's lifespan and reinforcing its value proposition within the context of at-home use. In conclusion, the FADAKWALT 8212A emerges as a commendable choice within the mid-range market segment, effectively balancing performance, durability, and user satisfaction through its considerate design and manufacturing approach, making it a compelling option for those in search of quality and functionality but do not require extremely high-performance at a competitive price. We have identified three main functionalities that are key to the operation of the drill, namely the casing, the power and the rotary systems. The latter two are large sections that comprise themselves of many smaller key components.

2 Identification of Key Components

2.1 Casing

The casing of the drill is an integral part of the final assembly, contributing to the overall appearance and functionality of the tool. Initially, it serves as a housing for all the individual components necessary for the drill's operation. However, it also fulfils several other essential roles, including providing control and ensuring user safety through ergonomic design features. Additionally, the casing facilitates heat dissipation through strategically placed vents.

Upon closer inspection, the materials used in the casing have been identified as two different plastics. The green matte part is made of a 30% glass fibre reinforced polyamide 6 (PA6-GF30), whilst the black rubber-like part is some sort of thermoplastic elastomer (TPE). Justifications for these material selections were made. Due to the fiberglass inclusions in the polymer base, PA6-GF30 stands to be a strong but flexible material and has electrical insulating properties. Relative to unreinforced nylon, it exhibits higher strength and rigidity, improved heat resistance and better creep resistance, making it a more than suitable candidate for an appliance that needs to withstand a high amount of impact such as a drill.[1] TPE is used for the grips on the handle, as they are a versatile set of polymer blends that combine the look and feel of conventional rubbers with the processing efficiency of plastics. Above their melt temperature, TPEs exhibit thermoplastic behaviour, allowing them to be shaped onto the shell in a process called over-moulding to provide slip resistance on the handle. The addition of TPE is to provide enhanced grip and tactile comfort, contributing to the overall user experience.[2] Further enhancements to safety and ergonomics are achieved through the incorporation of indents on the grips.

2.2 Power

In our analysis of the cordless drill's vital components, we identified a battery from Creabest as the closest match to the drill's actual battery, which could not be located for direct comparison. The Creabest battery, with specifications closely mirroring those required for the drill's operation—such as a 12V voltage and 3000mAh (note that the actual battery is (12V, 1300mAh) Lithium-Ion capacity—serves as a proxy to understand the performance and design considerations of the drill's power source. Given the drill's specific battery is likely purchased in bulk and possibly customized with a proprietary casing for optimal integration into the drill's design, accurately estimating its price and specifications poses a challenge. The Creabest model, while not the exact battery used, provides insight into the type of battery technology the drill employs, highlighting the balance between power output, user safety, and convenience with its removable design. However, the intricacies of the drill's battery, including its bulk purchase arrangements and potential customizations, make it difficult to precisely assess its cost or find an identical replacement on the open market, reflecting the complexities involved in sourcing and selecting components for power tools. Overall, the battery is small, lightweight and fits the required needs for the product. The possibility to remove the battery allows for users to use different batteries which may have a larger capacity or use back-up batteries for longer for different uses.

2.3 Rotary

Within the rotary system, we have further split it up into four components: the motor, gearbox, clutch and the chuck. The drill features a **12V motor** that works together with a 12V battery that supplies electrical energy to the motor. An adjustable speed switch controls a potentiometer that varies the power supplied to the motor for the drill to increase its speed for a smoother experience. This motor is typically used in a cordless drill since it has a high power-to-weight ratio, making it ideal for portable use. It is likely to be bought from another company that specialises in making them and can be seen in other drill brands selling 12V cordless drills. Any consideration for improvement will therefore be disregarded as ultimately he materials selection will not be done in-house, a different voltage of motor might be something to consider in the future. The drill uses two **planetary gear sets** connected in series for power transmission. Planetary gearboxes are commonly used in cordless drills due to their high torque density allowing for compact size and ability to handle high torque loads. The use of two planetary gearboxes connected in series allows for a wide range of torque and speed combinations, making it versatile. The gear ratio inside the gearbox determines the motor speed reduction and torque increase to the chuck. The gear ratio of planetary gear sets and the number of them connected in series are something to consider in the future, balancing cost, weight, compactness, and range of torque and speed. Gearboxes can be bought or produced in-house. In this case the complexity and level of precision of gears this small in size is high to ensure high power transmission efficiency and endurance. It is also made of a type of stainless steel and therefore quite complex in mass production. The drill incorporates a **21+1 adjustment torque clutch**, offering users precise control over the amount of torque – or rotational force, applied during the operation. The adjustable dial allows for easy selection of the desired amount of torque tailored to the specific task at hand. With 22 modes available, this feature provides greater control over drilling and driving operations, preventing damage to materials/fasteners, and promoting safety of the user. This freedom of adjustment lends to the great accessibility of the drill for variety of applications of mid-difficulty projects. The **chuck** is a critical component of the drill. Its primary role is to hold various types of drill bits or attachments securely in place while allowing them to rotate freely during operation. The chuck is designed to accommodate different sizes and types of drill bits, allowing users to switch between various tasks quickly and easily. This versatility is further enhanced by the utilisation of a keyless chuck in this drill. Keyless chucks do not require a separate tool in changing the bits, making changes faster and more convenient. Like in this case, most chucks are bought-in as they are a highly complex part that are better manufactured by specialised companies. Outsourcing the production of chucks to a design spec is often a strategic decision, the specialised companies produce better quality and more reliable chucks as they have the expertise and equipment dedicated to manufacturing chucks as opposed to if FadakWalt were to produce them in-house. This can also be more cost-effective for the manufacturing company, allowing them to focus their resources on other areas of the drill's design and production. The jaws that hold the drill bits are most commonly made of steel, and further plans on characterising it will be discussed in the characterisation plan of the report.

3 Characterisation Hypothesis

3.1 Casing

The incorporation of PA6-GF30 and TPE materials within the casing further enhances its structural integrity and functional properties. The PA6-GF30 will be manufactured through Injection Moulding. The presence of ejector pin marks on the interior surface of the casing provides evidence of this manufacturing method. Injection Moulding offers several advantages, notably its ability to achieve high engineering precision in the mould. This hypothesis is supported by observations of intricate ergonomic features on the casing, and specific sections inside which seamlessly match the body of the product. Furthermore, the adhesive nature between the polymer casing and the elastomer covering, despite being attributed to a mechanical bond, suggests a coating method with applied force to ensure the cohesion between the two materials, most likely to be over-moulding.

3.2 Gearbox

The crux of the gearbox's performance centres on the metal used for the gears. The hardness and weight of the chosen metal are pivotal factors influencing the efficiency and longevity of the gearbox. The selection of a suitable metal not only affects the performance of the gearbox but also determines the feasibility of various manufacturing methods. Understanding the composition of the gears provides valuable insights into these manufacturing processes involved and the potential costs associated with them. The choice of gear manufacturing method hinges on surface finish and alloying requirements in terms of thermal properties. Gear hobbing is the first choice for precise tooth profiles in high-volume production. In terms of the processing of the metal itself, casting suits mass production of complex gears, with subsequent machining needed to refine surface finish. However, powder metallurgy offers control over alloy composition for superior properties, with post-sintering processes addressing surface finish needs.

3.3 Chuck

The selection of treatment and alloying for the jaws of the chuck is pivotal in achieving desired mechanical properties for efficient operation. Material choice itself is not included here as the chuck is a bought-in part whereby the standard measure is for steel to be used. Given the critical function of securely holding the drill bit in place, it's vital that the steel jaws have a higher hardness than the drill bit itself. While steel remains the predominant material choice for chucks, the level of hardening significantly impacts both cost and performance. Through careful consideration of treatment methods such as heat treatment, manufacturers can tailor the hardness and wear resistance of the steel jaws to meet specific application requirements. Additionally, the alloying ratios can largely determine the mechanical properties of the steel, ensuring optimal performance during use. The selection of treatment and alloying processes thus plays a crucial role in optimizing the cost-effectiveness and functionality of chucks being bought for the drill.

4 Characterisation Plan

With all this in mind, to understand why the manufacturers have chosen certain materials for the drill it is important to consider what they may have asked themselves. For the casing – What is the cost of the type of TPE we want to use? Is the tactility adequate for it's use case? This will then be solved by using FTIR to further understand what TPE was used and therefore if it really is cost effective. We also pose the quesion: What is the structure of the glass fibres within polyamide casing? For this, we plan to use SEM which will give us an idea of the length of the fibres and there orientation. We The gears propose many questions as the total expense can be made up of many cost centres. The material choice and processing determine both cost and mechanical properties that are important for their function. Therefore, a cost to hardness ratio should be found and, in turn, there question to ask would have been: How should the gears be manufactured? This is going to take a full range of techniques to fully investigate. This includes, LOM, Hardness test, SEM/EDX and XRD. Finally, for the chuck, it is clear that the main point of interest is the hardness of the jaws, and this is determined by the processing which also will influence the overall cost. Leading to the question of what is the hardness desired and how can that be achieved? As we know the material is a steel, all that is required is a Hardness test. Table 1 shows the different techniques and how much this will cost for our team to perform. The predicted spend is £3425 out of a £5000 budget meaning we are far off our spending cap with a lot of cash for unforeseen circumstances. As well as a relatively low operating time of 8.5 hours makes this investigation very plausible to answer every hypothesis and question. The GANTT chart in figure 1 shows our general plan as to how we would like to tackle the various tasks whereby the order in which different techniques are placed and booked in advance are very important. The extended bars represent flexibility of when experiments can be performed as they won't depend on each other. These dates may also change as bookings have not been made yet, hence the plan is to start preparation and etching of samples as early as possible.

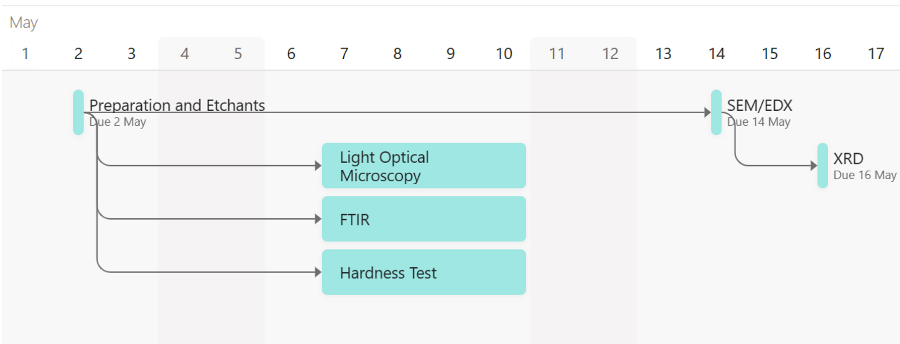
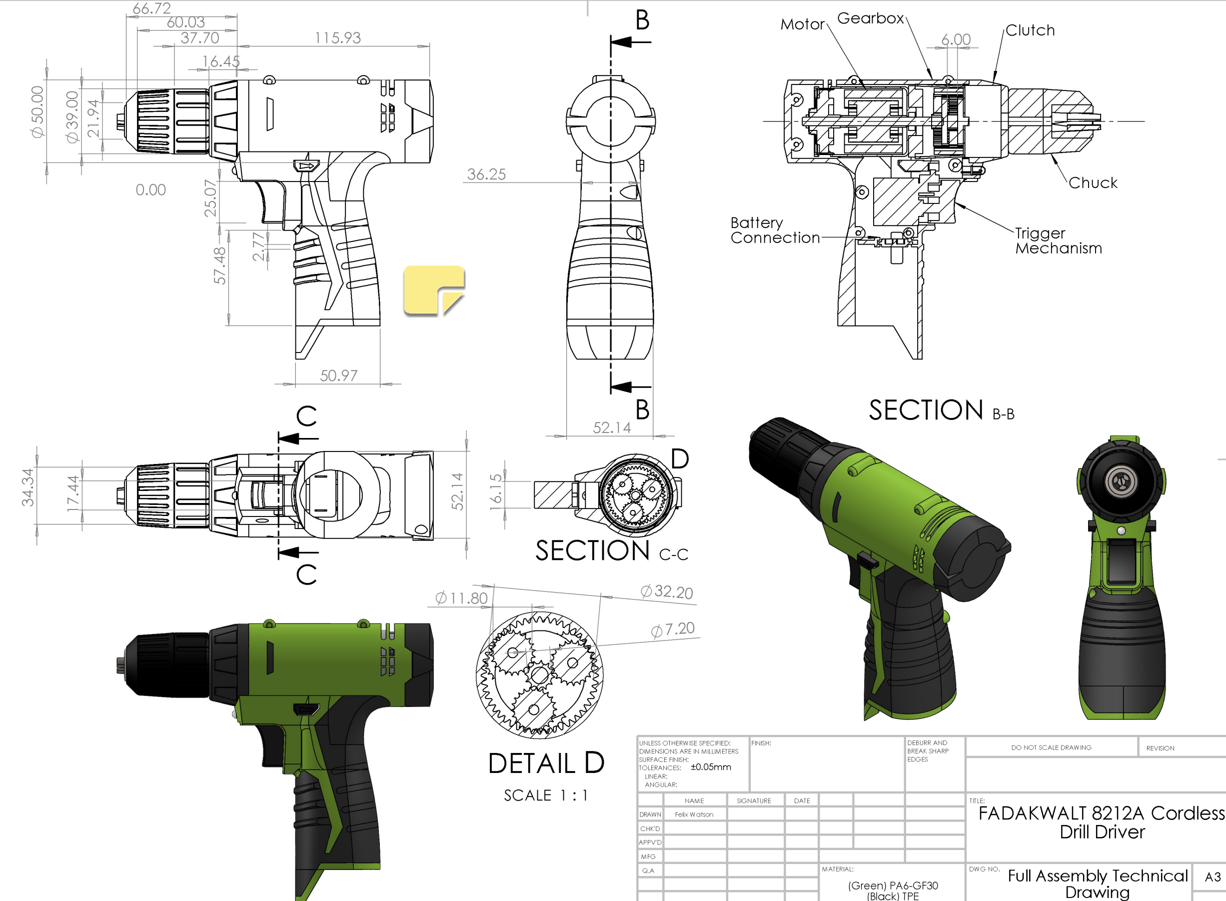


Figure 1: GANTT Chart for characterisation stage.

Technique	Cost £/hr	Frequency of tests	Time (hr)	Net Cost (£)	Sample Name
SEM/EDX	750	2	1	1500	Gearbox, PA6-GF30
XRD	500	1	0.5	250	Gearbox
FTIR/UV-Vis	500	1	0.5	250	PTE
Hardness	500	2	1	500	Chuck, Gearbox
Prep	250	5	3	750	Gearbox, Chuck, PA6-GF30
LOM	250	1	0.5	125	Gearbox
Etchants	50	1	1	50	Gearbox
Total			8.5	3425	

Table 1: Predicted spending across the characterisation stage.



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DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES: ±0.05mm
LINEAR:
ANGULAR:

FINISH:

DEBURR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	Felix Watson		
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL:
(Green) PA6-GF30
(Black) TPE

WEIGHT:

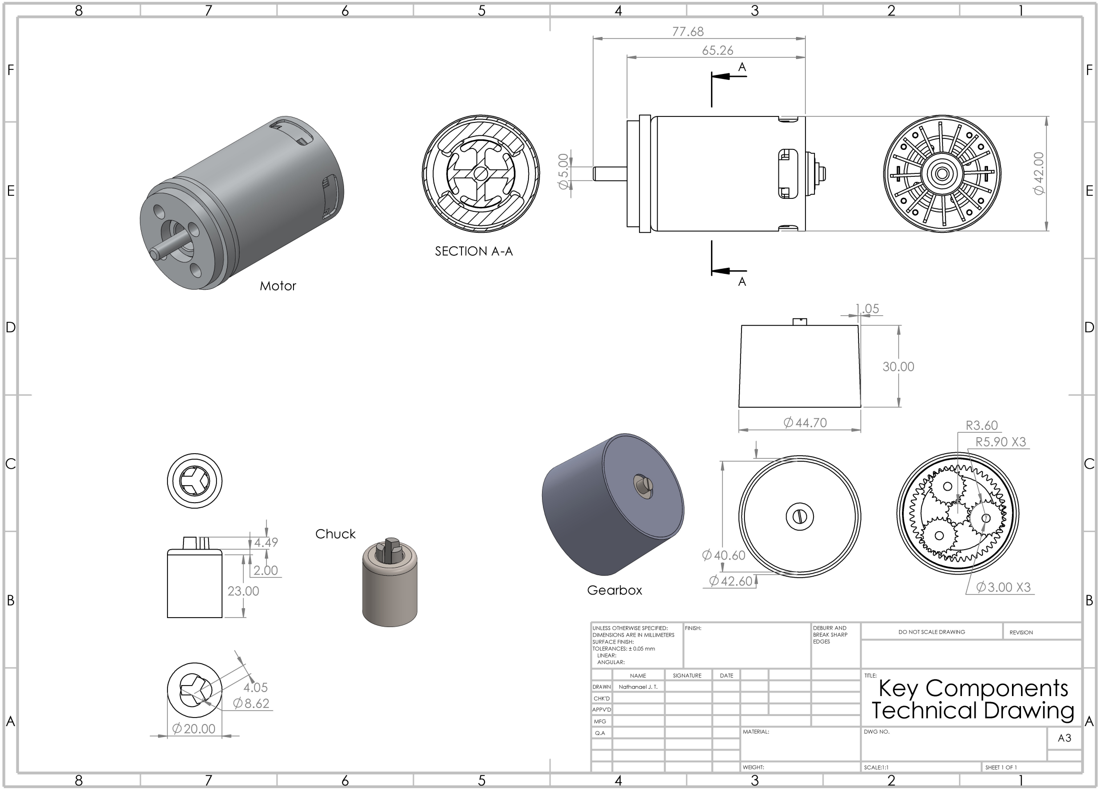
TITLE:
FADAKWALT 8212A Cordless Drill Driver

DWG NO.
Full Assembly Technical Drawing

A3

SCALE:1:2

SHEET 1 OF 1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Gearbox
Chuck
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2.00
23.00
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Key Components Technical Drawing
MATERIAL:
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SHEET 1 OF 1

5 Appendix

5.1 Contribution

Marcus Chien: Power functionality section, Description of item and identification of key components, Chuck and motor CAD models (Joint)

Freddie Johnson: Characterisation Hypothesis, Characterisation Plan, Power/trigger mechanism CAD model

Folake Olusanya:

Jeanne Tay: Casing and Rotary (chuck) functionality sections, General report structure planning, Chuck CAD model (Joint)

Nathanael Tjoa: Gearbox and motor CAD model (Joint), Key components technical drawing, Rotary (motor and gearbox) functionality sections

Felix Watson: Executive Summary, Casing CAD model, Full model assembly and technical drawings, Final edits and formatting

References

[1] EuroPlus, PA6 GF30: Key features uses, https://europlas.com.vn/en-US/blog-1/pa6-gf30-pa6-30-glass-fiber-key-features-uses, (accessed: 2024-03-13).

[2] TWI, WHAT IS A THERMOPLASTIC ELASTOMER (TPE)?, https://www.twi-global.com/technical-knowledge/faqs/what-is-a-thermoplastic-elastomer-tpe, (accessed: 2024-03-13).