



DESIGN FOR X PROJECT TASK 1

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MAY 29, 2023

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Executive Summary

This report is covering a case study carried out on a prototype tool that is going to be manufactured from tool steel in the future, but before that is done, we decided that it would be best to prototype the tooling to test its fit into the machine clamps. This report will also cover what additive manufacturing methods are available to us, these will include; Fused deposition modelling (FDM), Stereolithography (SLA), Selective laser melting (SLM), Electron Beam Melting (EBM), Digital Light Processing (DLP), Binder Jetting, Material Jetting and Laminated Object Manufacturing. The three main methods used are FDM, SLA and SLS; these methods will be further expanded on during this report.

Further into the report it will cover the chosen method used for the additive manufacturing processed that will be used, to expand upon this point it will also cover the advantages and limitations that this method comes with. For example, the chosen method was FDM as this was an affordable option that is easy to implement and use, but the limitations for this method would be its limit in material selection and the post processing required on most products. During the design of the model a few different techniques were also used and will be covered during the extent of this report, these included the programmes Solidworks and Fusion 360. A mixture of tools, these included, cut extrudes, boss extrudes, fillets and chamfers, all these tools are explained in further detail. For further evaluation of the part a generative design tool was used to help in decreasing the mass of the component.

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Introduction

This comprehensive report will explore into the details around the selection process of the component for this current case study. By inspecting the choices made in conjunction with the selection, it will draw a picture on the many factors that influenced this decision-making process, ensuring an in-depth analysis of the case studies groundwork. Moreover, this report will go beyond the component selection and highlight the chosen Additive Manufacturing (AM) process that was finally chosen for this case study. Through evaluation of several Additive Manufacturing processes, it will highlight the rationale behind the decision made based on the advantages, disadvantages, and compatibility for this case study. To add upon the selection of the chosen additive manufacturing method, this report will also delve into the design tools and techniques used during the case study.

To ensure that an inclusive understanding of the Additive Manufacturing constraints encountered during this case study, this report will also highlight various challenges faced through the additive manufacturing processes. explicitly, this report will cover key restraints such as shrinkage distortion, porosity, support structures, post-processing techniques, and costing calculations. By methodically examining these constraints, it can give a valuable insight into the impact that they had on the overall manufacturing process.

By Encircling all the crucial elements stated above, this report will offer a comprehensive and insightful understanding of the component selection, the chosen Additive Manufacturing process, the designed techniques and tools used, and the constraints encountered throughout the additive manufacturing process.

Main Findings

What component was selected?

The component selected for this case study was a unique tooling piece that was designed to specifically fit into our panel bending machine (RAS). This tooling was specifically designed so that it could fit into the corner of the fold, and then move itself out of the way when the tooling retracts. This tooling was needed to ensure we kept the folding line all the way to the edge of the material while still being able to remove the finished product with little to no damage. The model of this tooling can be seen in Figure 1 (RAS corner tooling front) and in Figure 2 (RAS corner tooling back).

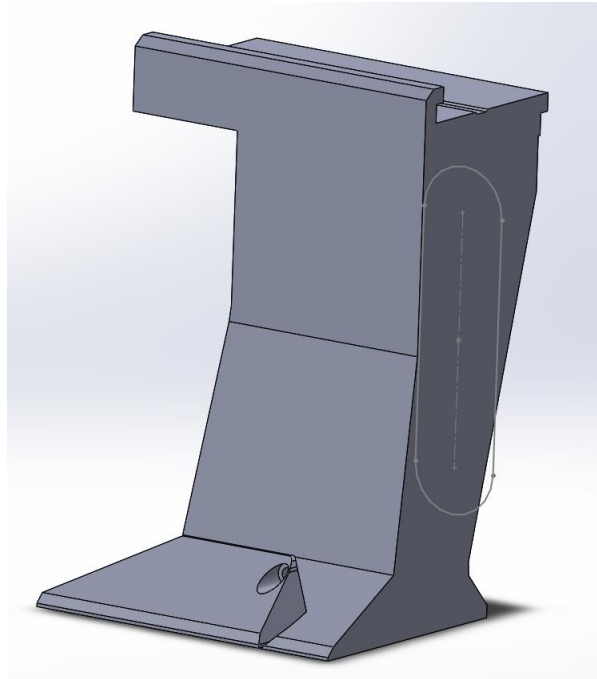


Figure 1 (RAS corner tooling front)

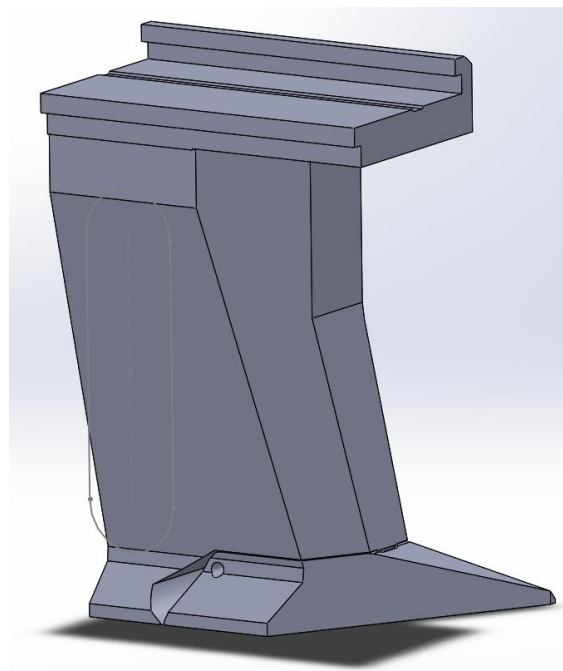


Figure 2 (RAS corner tooling back)

Why was it selected?

The tooling of the RAS was selected for this case study as this item was due to be produced by a machine shop that would cost the company a large amount of money due to its shape and the required material, it was thought to be a good idea to produce the part cheaply to ensure that the design was correct and it interacted with the machine correctly. This ensuring that we use the fail-fast method to ensure that all errors and design mishaps happen in the trial stages (Tullis, Albert, 2004).

What Additive manufacturing methods are available?

Currently available to the market there are 9 different types of additive manufacturing methods that can be used, these are called, Fused deposition modelling (FDM), Stereolithography (SLA), Selective Laser Sintering (SLS), Selective Laser Melting (SLM), Electron Beam Melting (EBM), Digital Light Processing (DLP), Binder Jetting, Material Jetting and Laminated Object Manufacturing. While there are a few options to choose from this report will focus on the top 3 methods used, these methods are, Fused Deposition modelling, Stereolithography and Selective Laser Sintering.

Fused Deposition Modelling is considered the most popular method of 3D printing as it is widely assessable across the globe and affordable at a large range of price points. These machines are commonly used by hobbyists, small businesses, and sometimes even larger businesses. The FDM printers are most used to print functional prototypes, concept models, and low-cost low-volume production parts out of a wide selection of thermoplastics. These plastics fed through a hot nozzle that will accurately lay down the melted plastic onto a build plate, layers of this plastic are then built up to create the desired object (Liu, Wang, Y., Wu, B., Cui, C., Guo, Y., & Yan, C. 2019).

Stereolithography is also a very popular 3D printing method, however this method is more commonly used to print high resolution parts that require smoother surface finishes. The SLA printers make use of a photopolymer resin that is cured by a very accurate UV laser. These printers are widely used in industries such as, product design, jewellery, dental, and various medical fields, as all these fields require the aesthetic finish and quality that this printer can offer. (Enamul Hoque, & Hoque, M. E. 2011).

Selective Laser sintering is a widespread method that is commonly used to create functional parts that have a complex shape. This is used in industries such as, Automotive, Aerospace and healthcare. SLS printers make use of a high-powered laser that is used to accurately fuse together powdered materials including, plastics, metals and even ceramics. This type of printing is renowned for the versatility it possesses and its ability to work with a large range of materials (Liu, Wang, Y., Wu, B., Cui, C., Guo, Y., & Yan, C. 2019).

What Additive manufacturing method was chosen?

The chosen method for this project was FDM. This method was chosen as it was an accessible and affordable to set up. As this process is known for being so accessible, it allows for a printer to be chosen at the price point that suits the buyer. For example, a hobbyist may be interested in a smaller more affordable printer that could cost around £100; but for a business they may need something more robust and bigger, this printer could then cost upwards of £500. Another advantage of choosing an FDM printer is that there is a large selection of materials available, these materials could include, ABS, PLA, PETG and even some specialised materials such as conductive materials. FDM was also chosen as it is very user friendly and was quick and simple to learn/teach others.

What are the limitations to Additive manufacturing?

While additive manufacturing is still evolving it still has its current limitations. One big limitation for this method is its material limitations, while a wide variety of materials can be used not all materials are suitable for 3D printing, for example materials that have a high melting point will prove challenging to print as with the current technologies that 3D printing utilises. Another large setback for 3D printing is its production speeds, when comparing additive manufacturing methods to mass production they tend to be very slow, this is due to the product being made from very thin layers that take a while to stack upon each other.

Size limitations also effect this method as additive manufacturing is often restrained to the build volume of the 3D printer, if large scale parts are needed it can prove difficult and can often require specialised equipment. Generally, when 3D printing there is a post processing method required, this could be anything from sanding the outer surface to running a metal part through a CNC machine to gain the desired finish. This process can add a large amount of time to some prints as they could require a large amount of post processing (Haleem, A., Javaid, M. and Saxena, A. 2018).

What design tools and techniques where used?

During this case study a few Design tools and techniques were used, the design tools used included Solidworks and Fusion 360. Solidworks was used to design the 3D model that we required to make; this model was made to be a replica of a tooling piece that we currently have. This model was then modified to the new tooling that we wanted to test. To design the tooling, I used a mixture of tools, these included, cut extrudes, boss extrudes, fillets and chamfers. Cut extrudes are used to subtract material from solid objects, to achieve this you first must create a 2D sketch of the profile you desire and then extending this sketch through the desired object, this will create a negative space in the shape of the sketch.

A Boss extrude is used to create protrusions and add volume to 3D objects, to achieve this it is very similar to a cut extrude. You first create a sketch of the desired shape; the next step is to extrude the shape by inputting a specific size or dragging the sketch in the desired direction. Fillets and chamfers were used in this model to remove sharp edges, enhance the aesthetics, increase structural strength and for ease part insertion. To use these tools, you must select the length and height of the fillet, you can then select the corner you require to filter and it will apply the fillet to the corner.

Fusion 360 was used to carry out a generative design study on the model, this allowed us to select all key features of the model that we did not want to change, then we inputted all operating stresses that the part would go through. The programme then generated the most optimal design that could carry the same loads with as little material as possible. This can create some interesting models that could only be achieved by 3D printing, the model can be seen in



Figure 3 (RAS tooling generated 1)



Figure 4 (RAS tooling generated 2)

Conclusion

From carrying out this case study the benefits and limitations of 3D printing became very clear, in this case study it was more focused on the creating of a one-off part that was going to be used to test the firing on the tooling before committing to a more expensive process. As shown in this report we can see that 3D printing is very useful when prototyping for project work and even for production work. As shown, there are many types of 3D printing that all have their own limitations and advantages, some of these included, speed of printing, surface finish, quality of print and even materials that can be used on the processes.

From taking into consideration all these factors it is obvious that 3D printing is an amazing process that can achieve making near impossible shapes and geometries, even though the material range is still limited, there is still a large selection that can be chosen from, but to print with materials such as metal and ceramics it can be a costly process. These processes still have along way to go but still have their uses in modern day production and prototyping.

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DESIGN FOR X PROJECT TASK 2

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JUNE 8, 2023

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Executive Summary

The main emphasis of this report is to cover how a prototype model can go from the prototyping scale to the mass production scale and what techniques may be used to aid in the decision of design changes and process selection. This report will cover the basics of what high-volume production is and what process can be used to achieve high-volume production, it will highlight CNC machining and go in depth about the injection moulding process. It will cover the benefits of injection moulding and give a basic insight into how injection moulding can be utilised in a high-volume production environment.

A concept design appraisal was carried out to gain the required information needed to create a design specification, this design specification was then used to define what the product was required to do and cover the target audience for this product. A manufacturing process proposal was also included in this report to briefly cover what process would need to set up to get this product into the mass production environment, this included What factors are needed to set up a new machine and how an assembly line works and what will be required to implement this.

All design and development work were also recorded in this report to ensure that all changes made to the design where rationally made, this included why some parts were removed from the design and some even combined to create one singular piece. Slight adjustments where also mentioned to help in the injection moulding process as certain profiles may struggle to be injected/ejected from the tooling cavity.

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Introduction

This report will aim to deliver a complete documentation of the techniques and processes involved in re-modelling a prototype wind turbine that was initially design for 3D printing, into a product that can be mass produced. Using and building upon the existing concept design the objective is to further enhance and optimize the components and assembly to create a higher manufacturability rate. The main goal is to be able to produce between a capacity of 1000 and 2000 per week.

During this report, various areas such as concept design appraisal, proposed manufacturing processes and the design and development work required for this project will be explored and recorded. To effectively convert the prototype model as seem in Figure 1 (Initial model) into a mass-produced product it is seen as essential to remove any unnecessary part, simplify complex components and ensure that the chosen high-volume production technique is suitable for the parts to be made. Therefore, research will be carried out into different methods of high-volume production techniques so that an understanding is gained to aid in the selection of the most suitable approach.

The aim of this study is to streamline the wind turbines design to enhance its ma manufacturability, and create an efficient production process that will meet the target capacity requirements. This report will deliver a valuable insight into the steps taken to transform the prototype win turbine into a product that is ready to be produced in a high-volume environment.

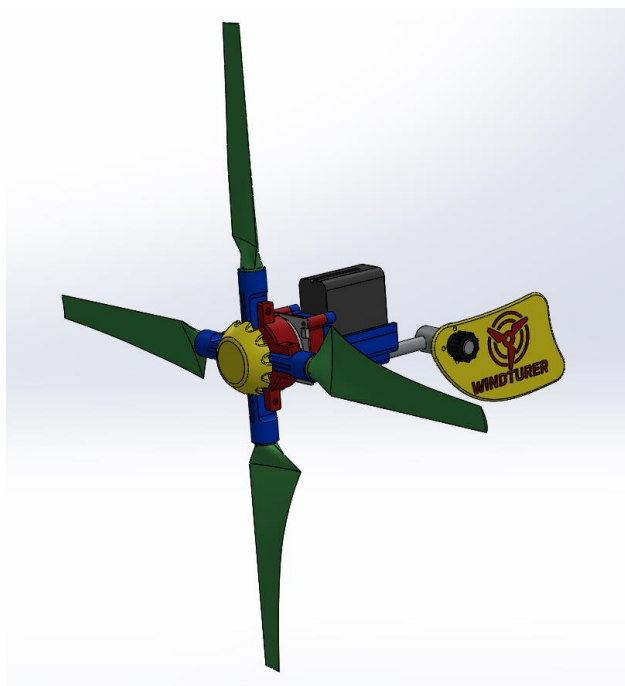


Figure 1 (Initial model)

Main Findings

What is high volume production?

High volume production is a manufacturing method where large quantities of products can be produced in a short period of time. This method usually involves the use of automated machines, assembly lines and efficient production system to attain and maximize production output. High volume production focuses on producing large quantities of products in a short time scale while still being able to maintain a consistent quality of the parts being produced. This type of production is often being used to produce high demand products such as, electronics, Cars, Food items and even household appliances.

When looking at high volume production there are a few key characteristics that can be seen, the main characteristic is scale; the scale for high volume production is seen to be large as products are usually produced to meet a high market demand. The next characteristic is automation, automated machinery is often used within this process as it can carry out repetitive tasks, reduce manual labour and increase production speeds. Assembly lines are also seen as a vital part of high-volume production as most products will have multiple parts that need some form of assembly, production lines move along in a sequence of processes where workers or machines will perform a certain task before the assembly continues along. Other characteristic includes, Standardization, cost efficiency and time efficiency. (Scharff, P.J, 2012)

What methods can be used in high volume production?

During high volume production there are many methods of manufacturing that can be used, these methods could include; injection moulding, CNC machining, assembly machines, Packaging machines and even machines such as CMM that will measure the parts for you to check tolerances for you. Injection moulding is used in the production of plastic parts, they do this by injecting molten plastic into a mould that will create the part using high pressure and will also create the part quickly. CNC machining is a computer numerical controlled machine that will use tooling to perform precision machining operations, these operations could include, cutting, drilling, milling, and turning. CNC machines are more commonly used in metal working industries (Taylor, Francis, 1961).

Concept design appraisal

The expected customer for this product will be assumed to be people that go hiking, off grid camping, fishing/hunting for longer periods of time and even for people going on expeditions. The target of this product would be to provide its users with a portable solution that can aid in the recharging of their devices. This product should be able to be assembled in little time while be able to be stored easily in a bag with other equipment they may have. This product will also take advantage of natural resources to produce the necessary power to charge devices. Parts for this should also be easily replaceable if they were to break as this product may be used in a rugged environment where it can get easily damaged.

By taking advantage of green energy production, it will increase its public perception as it will be a green source of power that will not cause damage to the environment when in use. Also, to increase the public perception of this product, it will have to look aesthetically pleasing to the customers and public. The Aesthetics of the product will play a massive part on how well this product will sell and

how the public will perceive it. Giving the turbine a professional colour scheme will be beneficial, use a bright colour will catch people's eyes and colouring the blades brightly could stand as a warning not to touch then while in use. As shown in Table 1 (Design Specification) a simple design specification can be made from this information.

Table 1 (Design Specification)

Design specification		
Aesthetics	What shape will it be? What colours will it be? Will it have texture?	It will have four blades that are removeable so it can take up a smaller area when stored. The colours will be either, grey or black with a bright colour on the tips of the blades to ensure safety. A Texture will be applied to the thumb screw for added grip when tightening.
Target audience	Who will this Target? What are the customers' requirements?	My target audience is outdoor adventurers, this can include, campers, hunters, hikers and even fishermen. The customer will require a portable way to produce their own power, this power should be enough to charge items such as, phones and cameras.
Environment	Where will it be used?	It will be used outdoor in rugged environments where winds could be high the weather may be wet.
Function	What must it do? What is its purpose?	It must be easy to set up and store away, while be able to produce enough power to charge its items such as phones and cameras. Its purpose is to produce green energy in places where power is hard to come across.
Manufacture	How will it be manufactured	The main assembly will be manufactures using injection moulding and assembly lines.
Materials	What material will be suitable?	The main body will be made from plastic so it will be light and the added flexibility will allow it to bend further before breaking when in transport.
Size	What general size will it be?	When stored it should be no bigger than a 2L bottle.
Quantity	How many are required to be produced?	Between 1000 and 2000 units should be produced per week.

Manufacturing Process Proposal

To get this manufacturing process implemented it would require the setup of an assembly line that will oversee assembly the parts together into its final assembly, these steps would include; fitting the motor into its adaptor, fitting the motor to the main body, assembly of the tail fin, test fit of the blades, wiring the motor to the battery dock and finally the insertion of the batter. All these steps will have their own station that will focus on the individual task they are set; it will also be beneficial to have a QC (Quality Control) station set up for the checking of the parts and assemblies (Banton, 2023). Buying in the motors, batteries and wiring would also be considered as making them ourselves would not prove to be beneficial.

Setting up the manufacturing of the parts will also be a big step to complete. The main thing to consider here is if getting the machines and running it, ourselves would be a good idea or if outsourcing the production to a separate company would be beneficial instead. If outsourcing we would need to consider how much each tool would be to buy and maintain as well as the transport links between the manufacturer and the assembly line, as if the links are inadequate, it will cause a delay on parts arriving and cause the imbedded carbon of each part to increase which will have an impact on the environment. If the manufacturing will be done inhouse we would need to consider how much each tool would be to buy and maintain. How much each machine would be to run, maintain and the employees needed to run it, also, the space required to house the parts and material.

Injection moulding has been chosen as the main manufacturing method as it is already a widely used method, it involves inject a molten material, usually plastic into a cavity to create the desired shape. Injection moulding has many benefits that can include, its versatile on being able to produce a range of different sized parts than can have complex geometries and still be able to manufacture them with precision, this also allows for the design of the product to be flexible as complex geometries are no issue. This method is also very efficient and yields some high production rates, while still being able to offer a large material selection. Injection moulding is also known for its consistent quality as it can reproduce the same part thousands of times with little to no variation between them. This method is also known to be low cost as even though the initial investment is costly it will product high-volume parts for pennies with low labour costs and a high material efficiency. We can also expect this process to be automated to where the material is feed autonomously and the parts are automatically ejected and placed onto the assembly line (Halsted, 2012).

Design and Development Work

This should include any techniques or methods which you have used to generate new designs or features. You should also clearly document any design for 'X' evaluation techniques or considerations. These could include the application of assembly analysis techniques, SCAMPER, as well as any risk management techniques (such as Failure Modes Effects Analysis) which you have applied.

As shown in Figure 2 (Blade) we can see that these two parts have been made into one singular piece, this allow us to reduce the numbers of the parts from the initial design, allowing for an easy assembly process as now these two parts will not have to be glued together during assembly. The bolts where also removed from the design as they where added unnecessary fixing to the model which would increase assembly time and the number of parts that needed to be kept on hand.

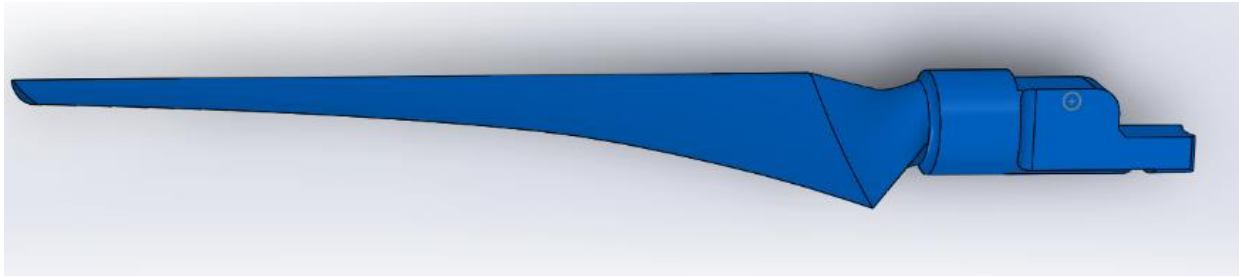


Figure 2 (Blade)

As shown in Figure 3 (Motor mount) the holes have also been removed as they were no longer needed and added another layer of complexity to the part. To further this part's development for mass production it will also be advisable to add a slight taper to the square faces of this part, this would allow the part to be released from the mould easier. Also, by changing the pitch of the threads we can further simplify this shape's complexity and further its ease of manufacturing by ensuring the threads are manufactured correctly.

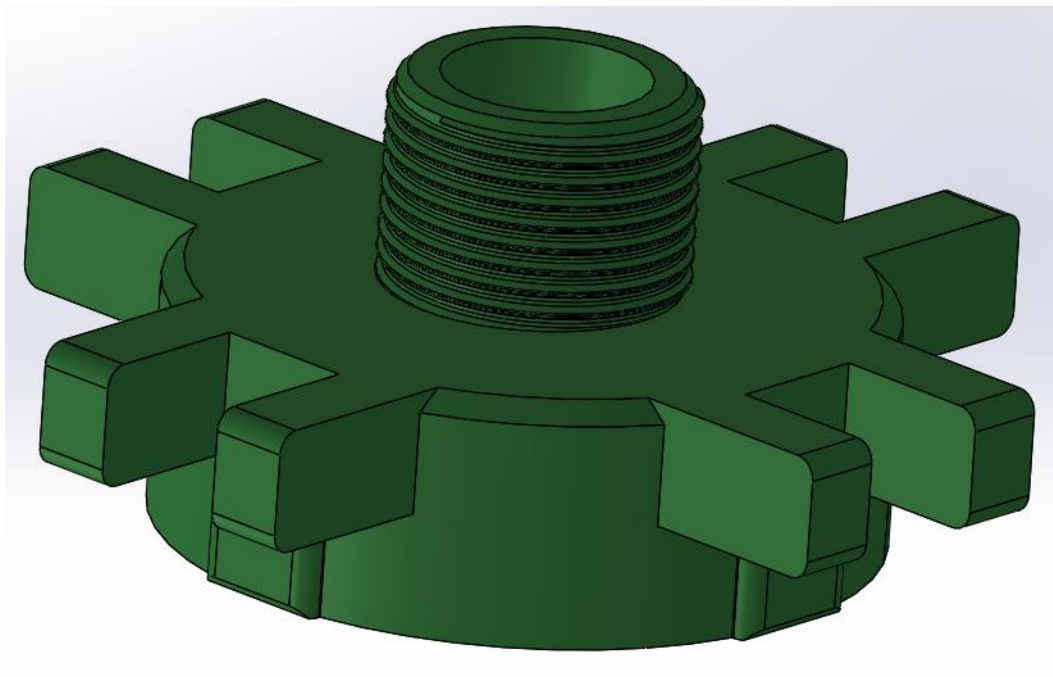


Figure 3 (Motor mount)

As it can be seen in Figure 4 (Spacer) the spacer could be removed from this assembly all together as all it is doing is adding extra parts to be produced, meaning that extra material and time will be required to produce this part. If during the development of this product we find out that we require this spacer it would be better to incorporate the spacer and the main body of the turbine as one piece. Again, this will decrease the parts needed and fixing required to assemble this product.

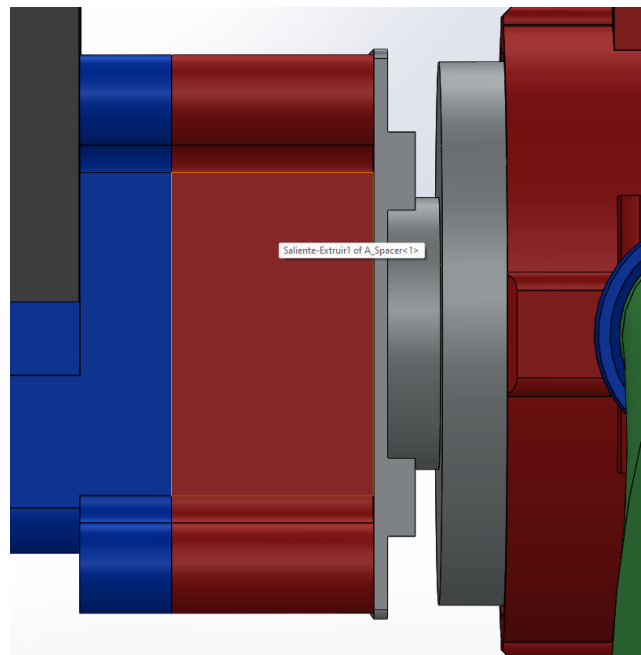


Figure 4 (Spacer)

When looking at Figure 5 (First clip) we can see that multiple parts have been used to create a clip that keeps the battery in place, this will require us to produce multiple different parts that could be eliminated from a design change. As shown in Figure 6 (Second clip) this clip is one piece and is included in the main body of the turbine, this will increase the complexity of the part but will also decrease the number of parts required to assembly this product. By using the flexibility of the plastic to our advantage we can make this design work by making slight adjustments to the design in Figure 6 (Second clip).

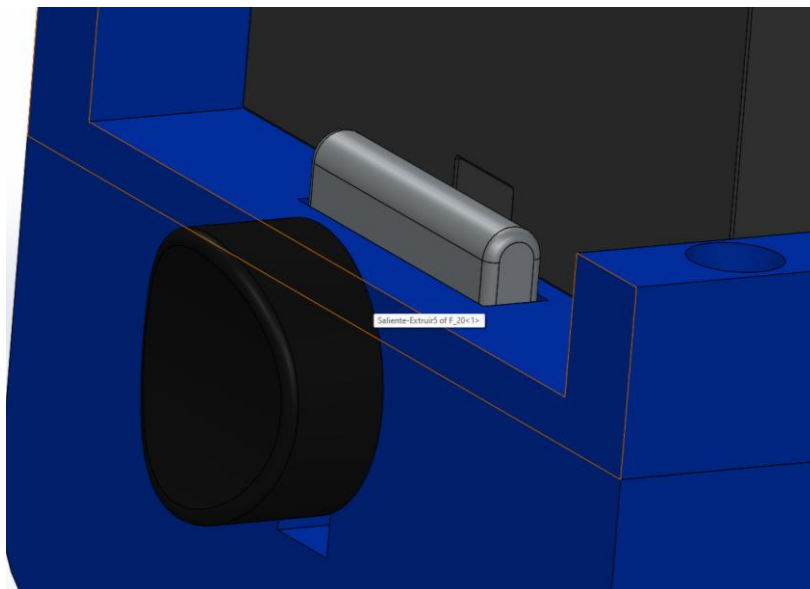


Figure 5 (First clip)

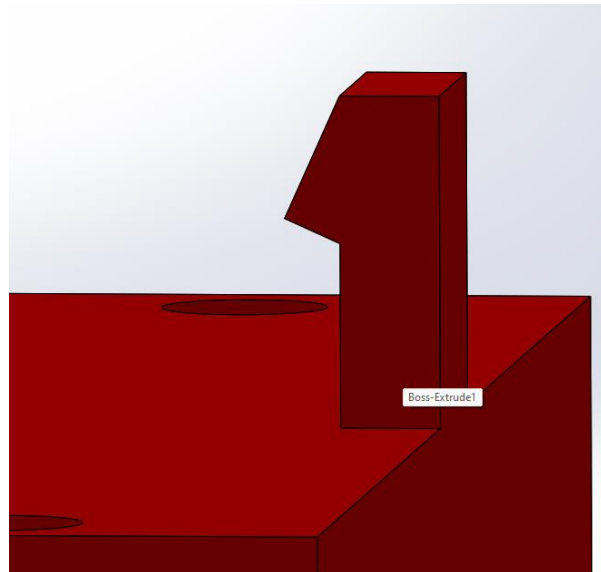


Figure 6 (Second clip)

This design still has many more changes that can be made to increase its manufacturability, by consulting with a specialist in this area and a specialist in injection moulding would benefit massively. The focus from editing this design would be to decrease the number of fixing and parts required to assemble and produce this product, using the flow chart shown in Figure 7 (flow chart) we can decide which parts are essential and which are non-essential.

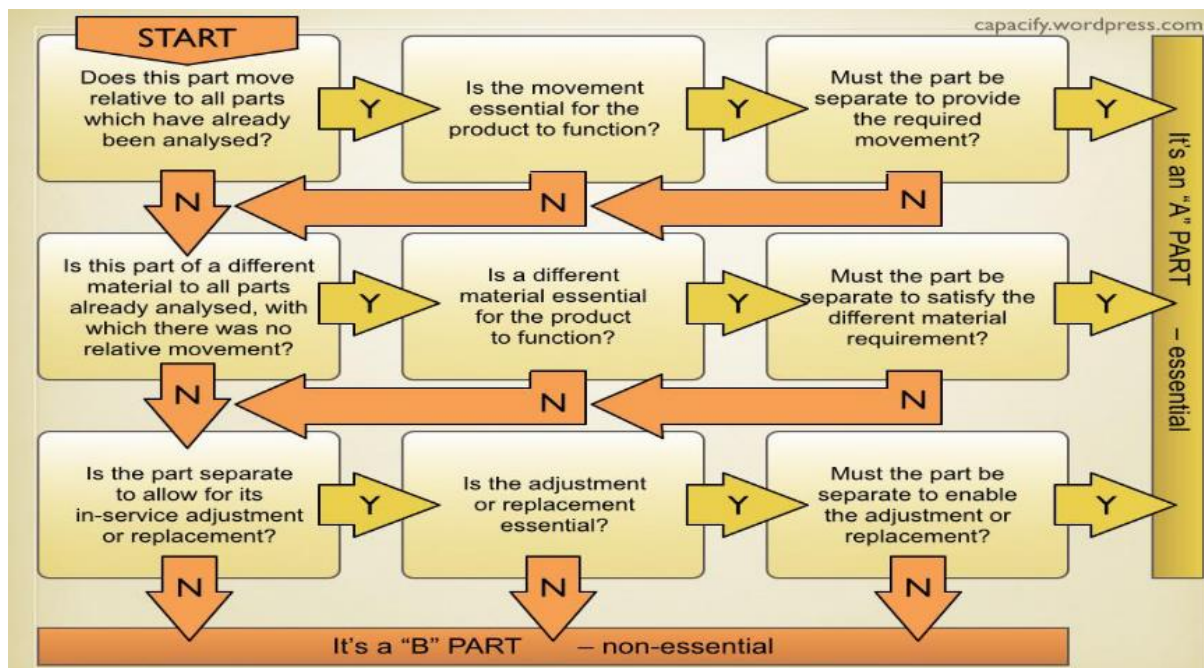


Figure 7 (flow chart)

Conclusion

Ultimately the changes made to the prototype will benefit the transition over to mass production for this product, but there is so much work that needs to be covered in order to get any product ready for mass production, especially when there are multiple parts that require assembling. From the information given a simple design specification was able to be produced to ensure that the

product achieved everything that we required, whether this was aesthetics or target market, with more information a more in-depth analysis could be carried out in order to create a full design specification. This would allow us to define more features that are needed to be included in this design.

The chosen material for this product was plastic, this is because it will not be affected by the weather and will not break easily when being transported, this material selection led to the manufacturing process proposal being based off injection moulding. Creating this product using injection moulding was chosen as this process has been heavily researched and is increasingly becoming more popular within industries. While there is a large set-up cost it allows for great flexibility when manufacturing parts out of multiple materials, it also allows us to create the small details with ease. As this product is aimed to be produced with plastic parts injection moulding allowed for ease of mass production as this process can be heavily automated to increase the capacity of production. A big benefit of this process is also how little material waste there is, this is mostly due to most rejected parts being able to be broken down and reused again.

Even though multiple changes were made from the original design there are still a multitude of changes and studies that can be carried out further to help with the swap over to mass production. For example, carrying out a Failure mode analysis to help in identifying potential failure point in the design and improving them, this would lead to increased customer satisfaction and operational efficiency. Other Design for "X" and assembly analysis techniques can also be used to further develop this design.

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