EASYPISTE 600

THE SNOWPARK SHAPING TOOL

10 PAGE SUMMARY

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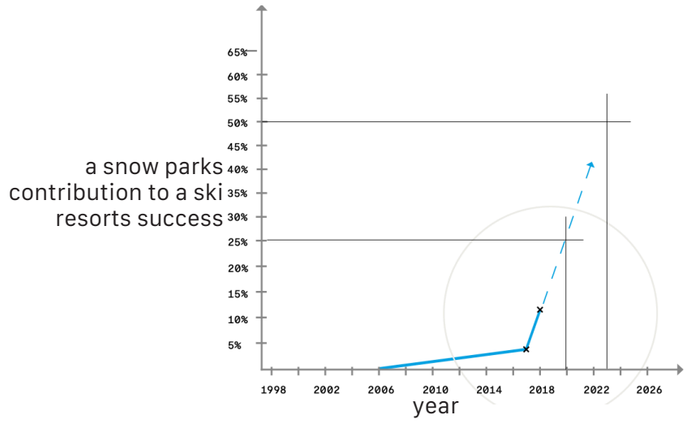
PROBLEM/OPPORTUNITY

THE CURRENT SITUATION

Due to the high risk nature of the sport of freestyle skiing and boarding, well built and well maintained snow park features are crucial. In the snow park construction and shaping industry of today, there are only 2 tools on offer. The main one is the £500,000, 9 tonne piste basher. This gigantic vehicle moves large amounts of snow around the mountain and prepares ski runs with its extremely powerful rear mounted rotary tiller. They are used regularly in large snow parks however are much too big & expensive to be used in smaller resorts parks. The other is the small, shovel like shaper tool. This is a sharp, aluminium rake that the snow park employees use to cut through icy lumps to leave a smooth, evenly shaped surface. Efficient use of this tool requires a lot of effort, time and skill from the user.

THE MARKET

With the inclusion of freestyle snowsports in the Olympics, the market for snow parks in ski resorts is expected to rise from 4% to 40% by 2022. With this increased popularity of the sport comes the need for easy and proper maintenance of all snow park features to ensure safety.



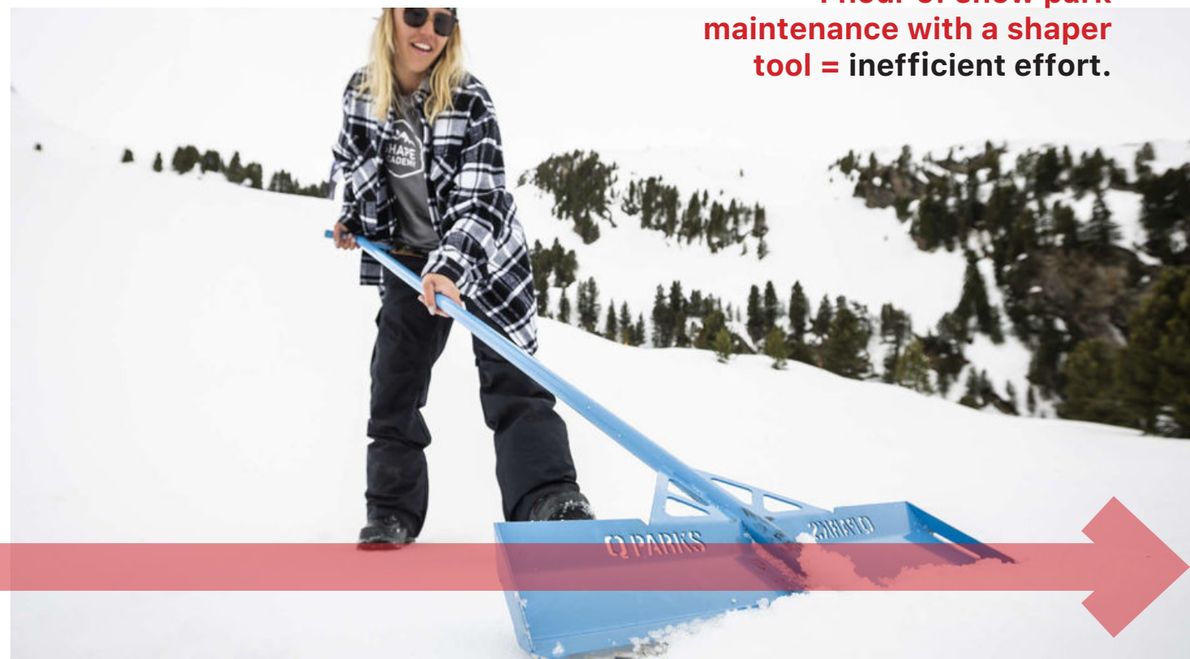
MARKET POSITIONING & USER

The two snow park shaping tools of today are at very opposite ends of the market. The piste basher weighs in at 9 tonnes and costs around £500,000. The park shaper tool weighs in about 4kg and costs around £300. Between these two products, there is the opportunity for a tool that can cater for the job where a piste basher is too heavy and expensive to use, and a park shaper tool is too ineffective to use.

From interviews with park shapers from both larger European snow parks and smaller Scottish snow parks, it was clear that the market that this product should be targeting was the smaller ski resorts with smaller snow parks. The ones who cannot afford or make efficient use of the large piste bashing vehicles on offer today. The shear scale of large snow parks make them a difficult market to target.

1 hour of snow park maintenance with a piste basher = 100 Euros

1 hour of snow park maintenance with a shaper tool = inefficient effort.



RESEARCH

SNOW FACTOR VISITS

From visits to Snow Factor in Glasgow, I was able to try out shaping with the current shaping tool myself. This visit showed the many problems that the shapers come across while trying to build and maintain the perfect park. The key problematic scenarios identified were:

- The common icy blocks are very difficult to break up and manipulate with the shaper tool.
- The piste basher is a limited resource and is sometimes too big for the job.
- The difficulty, effort and skill required when using the shaper tool.

From observing the staff and interviewing them, it was obvious they would be very keen on a tool that could help them better manipulate the snow, no matter the condition of it.


INTERVIEWS

Interviews with park shapers and the stakeholders were done to gain a deeper and more specific insight into the problem.
Euan Baxter, the head shaper at Cairngorm Mountain said:

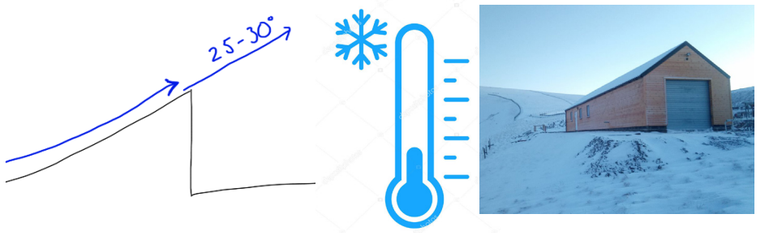
"The main problems the park crew have are; accessing the piste basher for use in the park and shaping the features with the current park shaper tool, it's no good at all!"

As expected, piste bashers are a limited resource due to their high cost and large size. Euan also gave an insight about snow being too icy to break up with the shaper tool.

ENVIRONMENT

Research into a day in the life of a snow park shaper showed how a hand-held shaping tool gets used and so brought some important requirements to light.

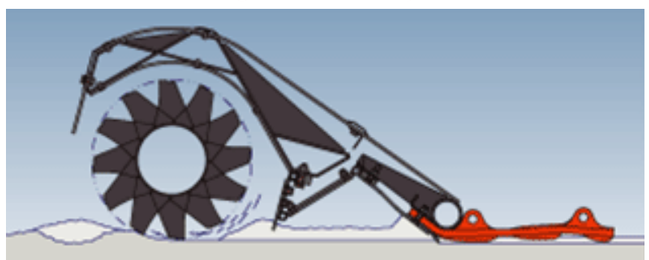
- Shaping occurs 1-2 times a day over the winter;
- Takes about 1-2 hours with the current shaping tool.
- The tool is stored in a garage on the mountain.
- A harsh, cold, snowy environment of up to -20°C.
- Snow park features include slopes up to 30°.



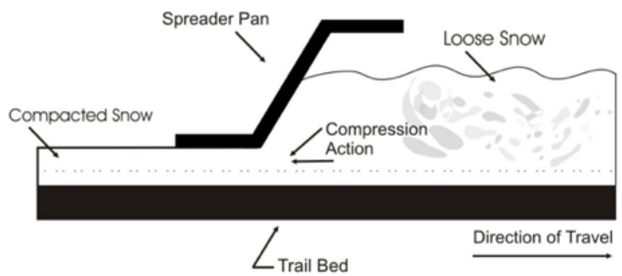
SNOW GROOMING PAPERS

The two parts to snow preparation include the tilling/processing of the snow with a high torque rotary tiller and the re-compaction/finishing of the processed snow with a comb. These papers indicated the importance of the control of the tiller's depth in the snow to cater for various snow types, as well as the downward pressure required by the comb.

1 pulverising with a rotary tiller



2 compaction/finishing with the comb



PISTE BASHER TECHNOLOGY

Analysing the existing piste basher tiller was useful in helping me understand what components and features may need to be included in my design if I was looking to effectively till snow. Features such as the tillers height adjustment to cater for various snow conditions were very important.
The piste basher tiller specification sheet showing multiple parameters was a useful resource for comparisons.

KEY REQUIREMENTS

- Eliminate the need for a skilled user - ease of use.
- Lightweight enough to be easily manoeuvrable but heavy enough to do its job well.
- Durability in cold temperatures.
- A tool to effectively & efficiently shape features on a smaller & more affordable scale.

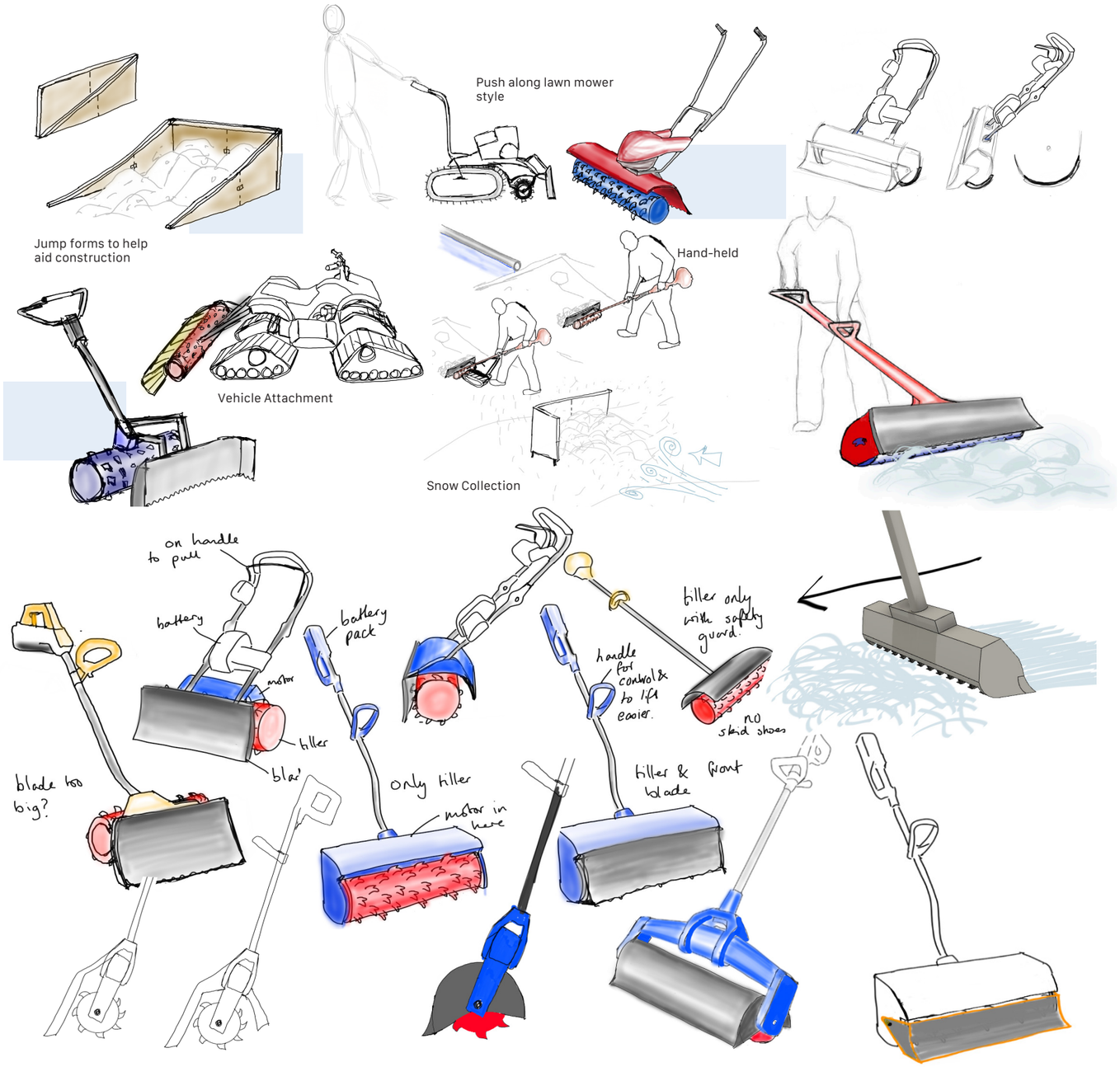
THE BRIEF

How can we enable smaller resorts, specifically Scottish resorts, to easily, affordably and consistently maintain safe snow parks, without the use of large piste bashers?

CONCEPT GENERATION

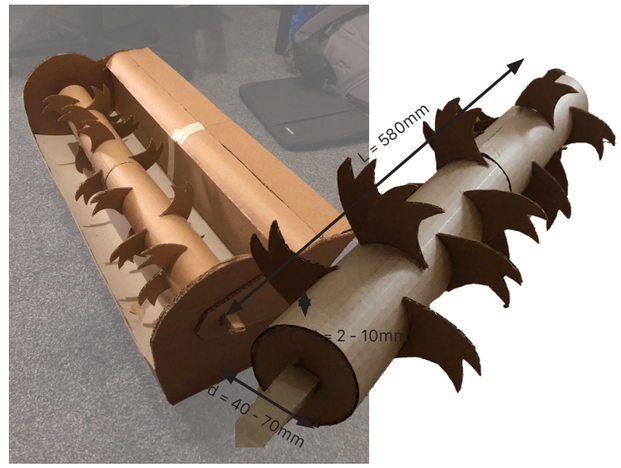
EARLY CONCEPT GENERATION

Multiple concepts were explored through sketching and evaluated against the design requirements/PDS. Initially, portability and manoeuvrability were a key focus and so it was evaluated that a hand-held tilling tool would be best.



SCALE PROTOTYPING

Scale prototyping allowed me to better visualise suitable dimensions for the product and specifically the tiller head. This prototype seemed worryingly big for a hand-held tool.



USER FEEDBACK

With the trade off between transportability and the required weight of the tool as an unsure aspect of the design, user feedback from local park shapers/user group confirmed my thoughts that a heavier tool could be better/needed:

"From personal experience I would rather a heavier "do it all" tool with transport issues than a lighter "only half the job" tool that I could get to the job."

With this being said, the availability of snowmobiles for towing in small ski resorts was researched:

"Having a ski-doo to tow should not be a problem - they are an abundance compared to snow-cats."

DEVELOPMENT

HOW MUCH FORCE IS REQUIRED TO GROOM SNOW?

BEFORE FURTHER DEVELOPMENT, THE POWER REQUIREMENTS FOR A TILLER IN SNOW WERE FOUND.

EXPERIMENTS & COMPARISONS

Experiments with functional prototypes in snow allowed me to estimate and calculate values of the required torque for the tiller in my design. Another experiment with a comb prototype was done to find values for the pressure and therefore weight required to effectively compact and groom out snow. The results from these were compared with the theoretical size comparison results to estimate a final value for the required torque and therefore power.

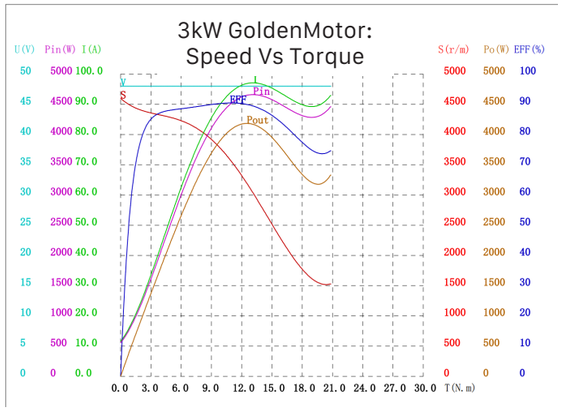
POWER REQUIREMENTS

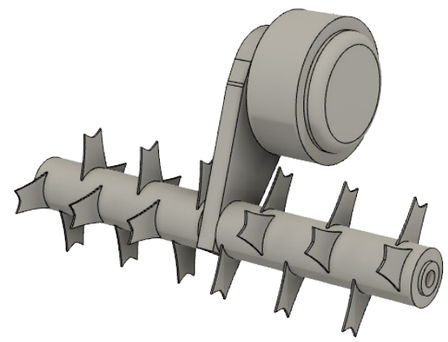
$$P = \frac{F}{A} \qquad P = T \times \omega$$

- Required torque: **80Nm**
- Required r.p.m. **400rpm**
- Required power: **3kW**
- Required pressure: **1800N/m²**

The required power was far larger than anticipated and would require a large motor & battery. So, development of a larger, heavier push along tool began.

MOTOR SELECTION & LAYOUT





Through comparisons of specifications, a suitable motor with sufficient rated torque and rpm was selected. From this a necessary gear ratio could be calculated, a gearbox could be chosen and the form of the design could be developed around the main components. After evaluating multiple layouts, It was concluded that a chain drive in the middle of the tiller was the best method of power transmission.

$$Gear\ Ratio = \frac{rpm(input)}{rpm(output)} = \frac{3191}{400} = 7.98$$

$$Torque(ouput) = G.R \times Torque(input) = 7.98 \times 12.52 = 99.88Nm$$

$$Torque(actual) = Torque(ideal) \times \mu(efficiency)$$

$$Torque(actual) = 99.88Nm \times 0.9 = 89.89Nm$$

BATTERY CALCULATIONS

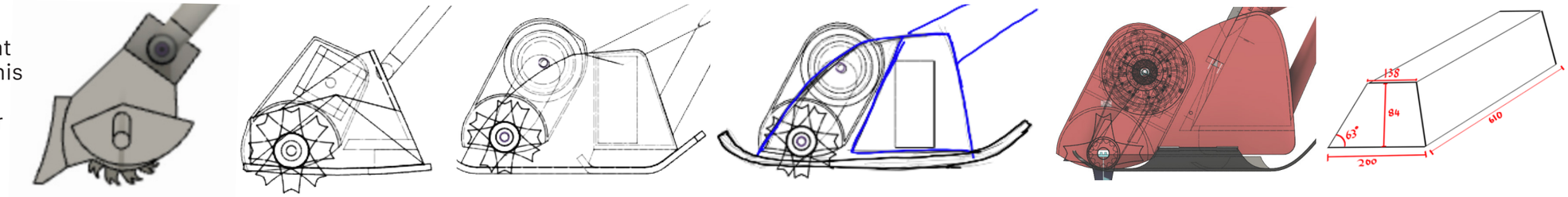
The motor load current and a run time for the product was specified. This allowed the required battery capacity to be calculated:

$$Battery\ Capacity = Run\ time \times Load\ current$$

$$Battery\ Capacity = 0.667 \times 85 = 56.667Ah$$

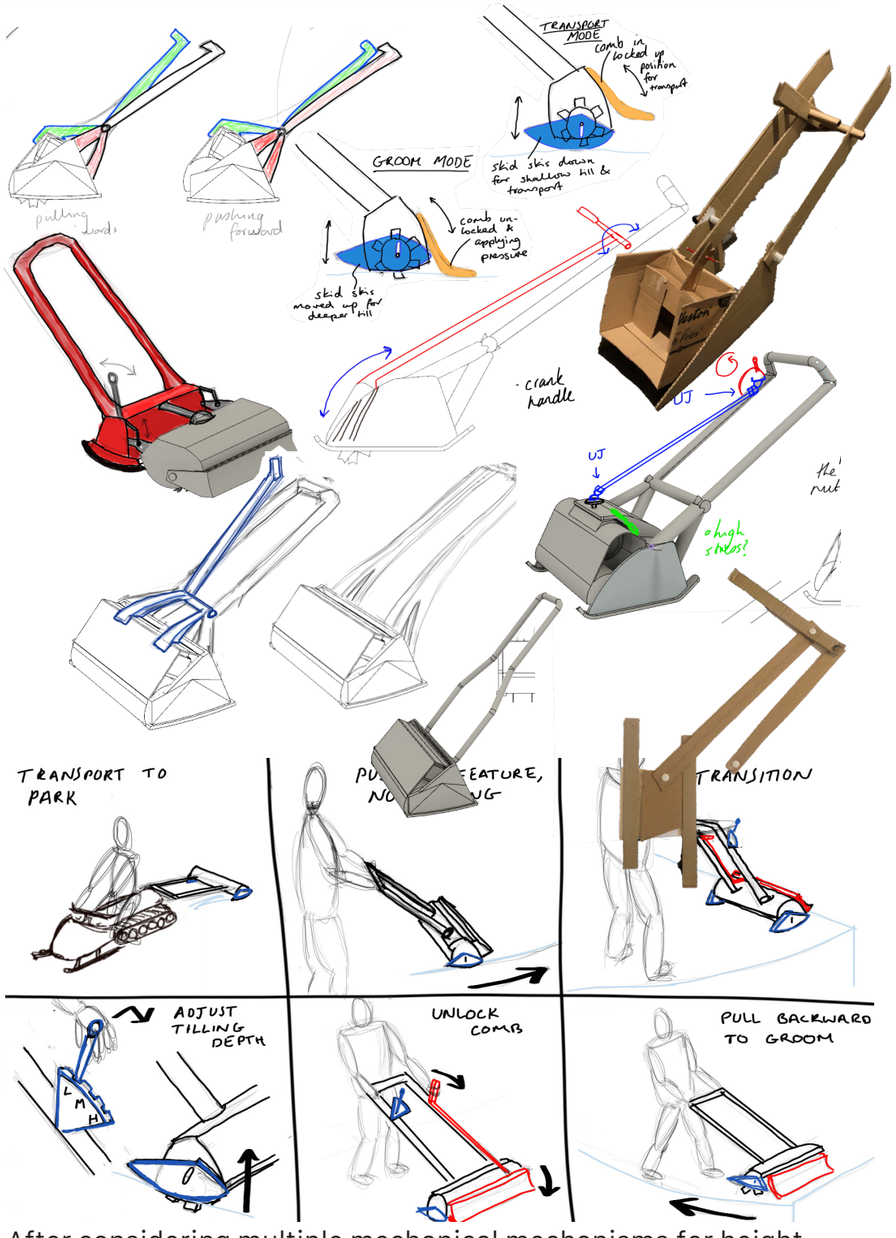
FORM FOLLOWS FUNCTION

The size of the battery, motor & gearbox instigated the development of the larger base. It was realised this base could easily house the large battery and provide space for other electrical components if needed.



DEVELOPMENT

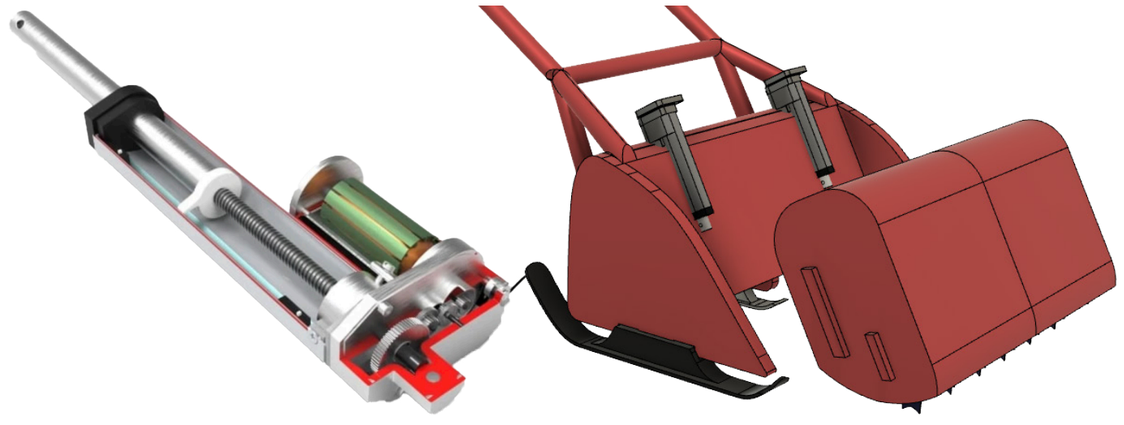
TILLER DEPTH ADJUSTMENT



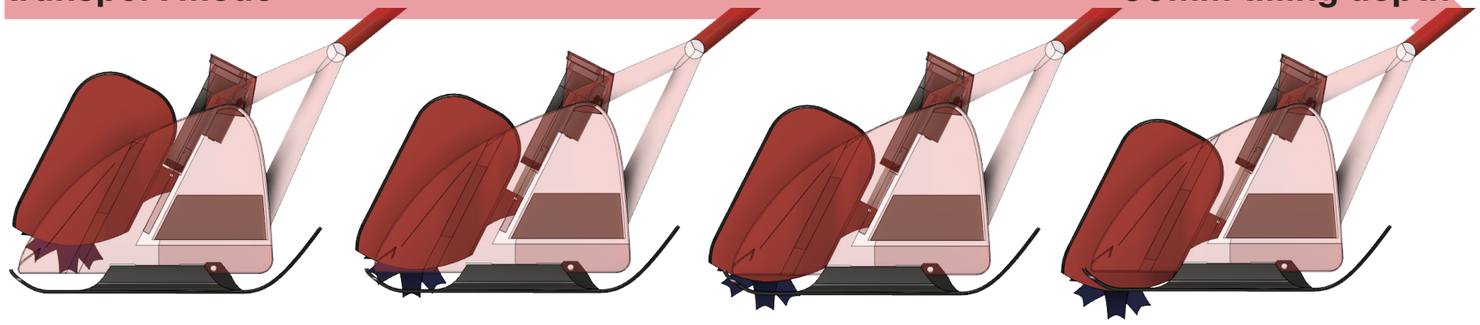
After considering multiple mechanical mechanisms for height adjustment through sketching, calculating and modelling, looking back to the user journey of the product helped me to evaluate what would be best. The frequency of the tilling depth adjustment led me to moving away from potentially difficult mechanical systems that would require a lot of human force to an easily controlled, effortless electrical system. This stage of development also helped me to understand & refine a concept with a rigid ski base & adjustable tiller head, rather than vice versa.

ELECTRICAL DEPTH ADJUSTMENT

With an abundance of power already in the design from the large battery, electrical components could be easily installed. Electric linear actuators were chosen as the method for adjusting the height of the tiller head. These readily available electronic lead-screws met all requirements and could provide more than enough force to lift, lower and statically hold the tiller head. After calculations and learning more about actuators, it was decided that the use of 2 actuators and the addition of guide runners would structurally benefit the design massively.
It was also realised here that the use of linear actuators could allow the tiller head to be raised high enough above the snow to provide a "transport mode" - allowing the product to be safely moved without having to till.

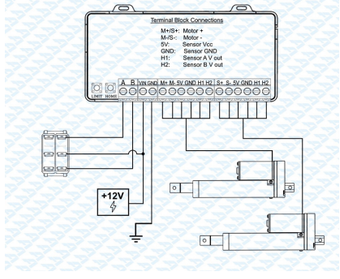


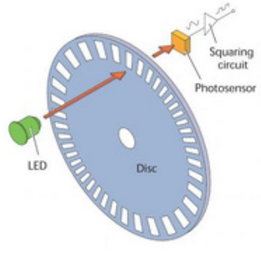
transport mode **50mm tilling depth**



READILY AVAILABLE COMPONENTS

Online research showed Firgelli Automations could affordably provide feedback actuators that could be synchronously controlled through the use of their pre-programmed controller. Requirements for the actuators application could be defined and the 100mm, 2224N, IP66 rated optical feedback actuators were selected.

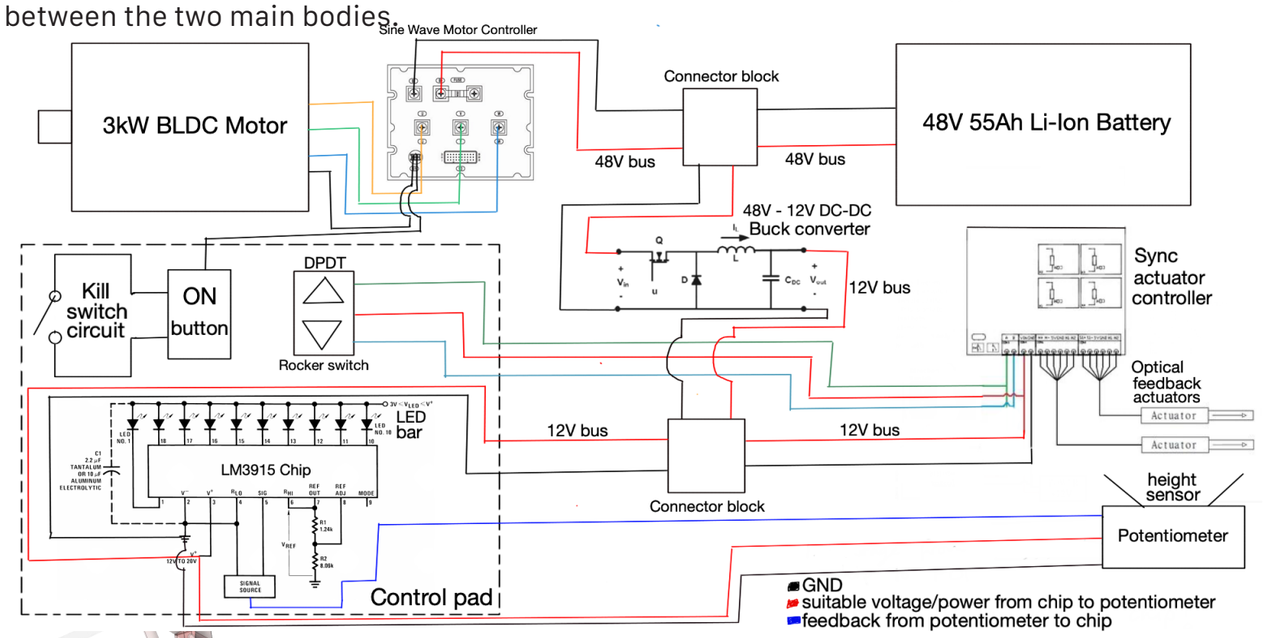


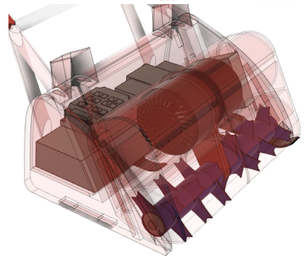


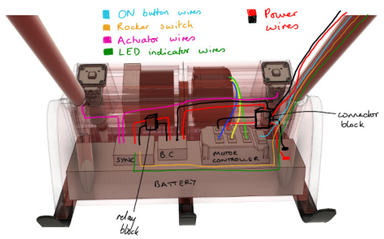
DEVELOPMENT

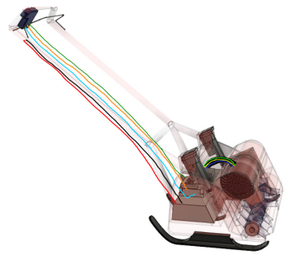
ELECTRICAL WIRING DIAGRAM

A topological wiring diagram helped to understand what exact electrical components were needed and how they should be connected. Integration of components and electronics into the product could then be done. It also helped to understand what wiring should be connected between the two main bodies.



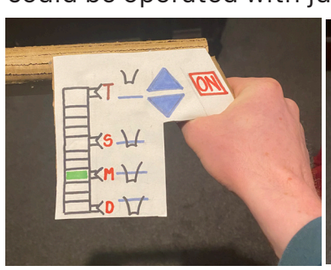


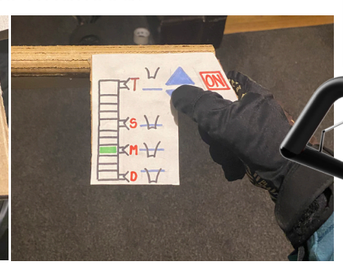


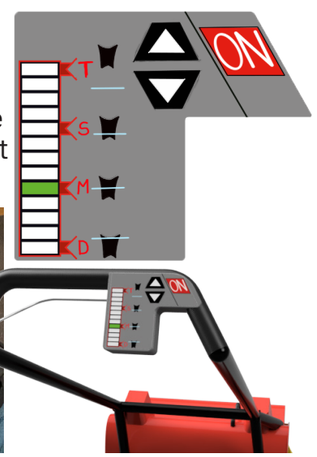


CONTROL

A simple, intuitive and easy to read control system for the height adjustment was developed with the use of readily available components; a rocker switch, a height sensor potentiometer, a monolithic integrated chip and an LED element bar. The control pad was ergonomically designed to be easy to use "on the fly" through prototyping and testing. A control pad that could be operated with just one gloved thumb was finalised.



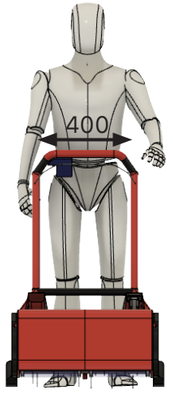


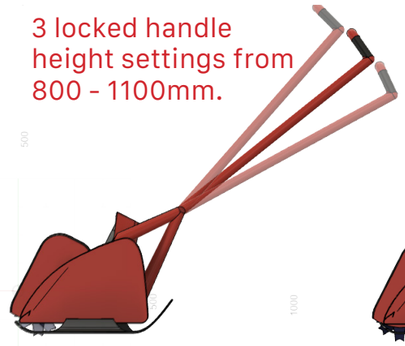


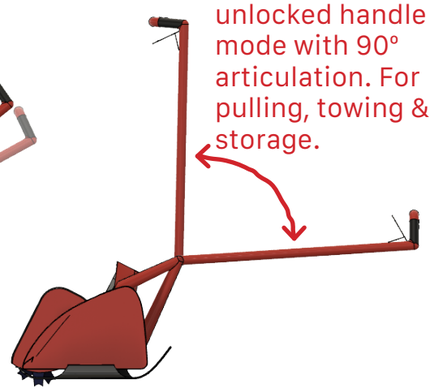
HANDLE DIMENSIONS

From looking at existing lawnmowers, anthropometric data, ergonomics studies of lawnmower handles, using 1:1 CAD models and testing prototypes, suitable dimensions for the handle and it's height were able to be defined. Testing the prototypes on slopes identified that the handle would need to have an articulated mode when in grooming mode for comfortable, easy use when pulling backwards and over transitions.

Dimension	Male(percentiles)			Female(percentiles)		
	5%	50%	95%	5%	50%	95%
Hip Height(L)	850	935	1020	750	820	890







WEIGHT TESTING

With the overall product being quite heavy, the use-ability of pushing the machine up a snowy slope was a concern. A rough prototype was tested to find that 40kg was a suitable weight. Re-design of the main bodies and material selection contributed to reducing the weight to 40kg.

PRODUCT OVERVIEW.
SHAPING PERFECTION.

SAFETY
"kill switch" lever makes sure there is no room for danger

CONTROL
control pad at the handle allows for on-the-fly adjustment

ARTICULATED HANDLE
Ergonomically designed handle for ease of use on any shape of snow park feature

ACTUATORS
electric linear actuators precisely adjust the tilling depth

BATTERY
High performance Li-Ion battery ensures long lasting power in cold temperatures

GUIDES
polyurethane block guides support & ensure smooth adjustment

SKID SKIS
Large smooth ski runners ensure ease of portability

FINISHER
A lightly flexible polyurethane comb leaves an evenly groomed surface

HIGH TORQUE TILLER
A 600mm wide steel rotary tiller pulverises any icy lump or bump in its way

3KW BLDC MOTOR
Electric vehicle motor provides more than enough power

EASY SERVICE
Designed with dis-assembly in mind to ensure replace-able parts, easy servicing and long lifespan

EASYPISTE 600

USER JOURNEY

The product will be stored inside the ski resort garage on the mountain.

It will be left to charge overnight/between shaping shifts. The user will unplug it from charge when about to be used.

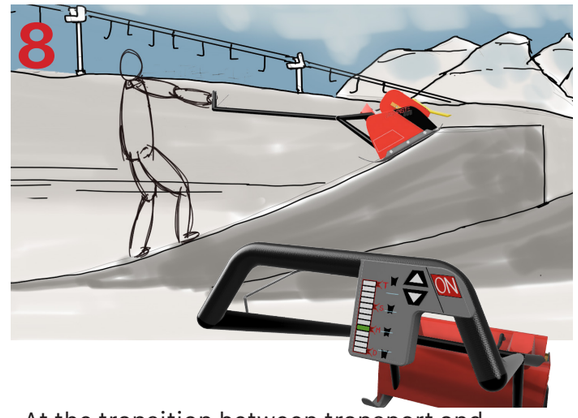
The user will pull(or push) the device out of the garage on its skid skis with the tiller head in transport mode(raised above the ground).

The park shaper will then, with the handle articulated, attach the handle to the back of the snowmobile/snow vehicle.

It can then be towed by the snowmobile to the work area - usually the snow park but could be used for most pisteing jobs on the mountain.

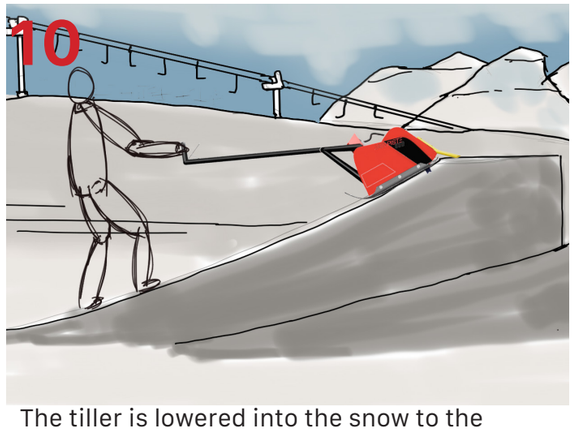
The device is detached from the snowmobile and the handle height is adjusted to lock in a comfortable position for transport/pushing.

With the tiller head still in transport mode, the user pushes it up the un-shaped jump or to the desired position to groom

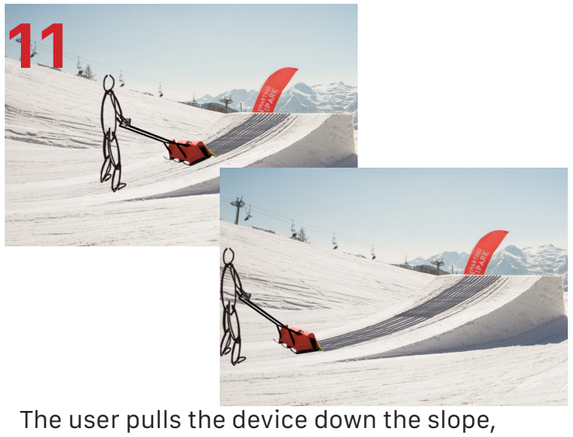


At the transition between transport and grooming i.e. top of the feature, the user will look to the control pad to prepare to groom.

The safety lever will be pulled and the ON button will be pressed to start the rotation of the tiller. The rocker switch will be pressed.



The tiller is lowered into the snow to the desired depth(indicated by the LED bar). The handle is then unlocked to become articulated to allow comfortable handle height for pulling.



The user pulls the device down the slope, leaving an even, shaped finish on that “strip”. The tiller will then be stopped & raised to transport mode again.

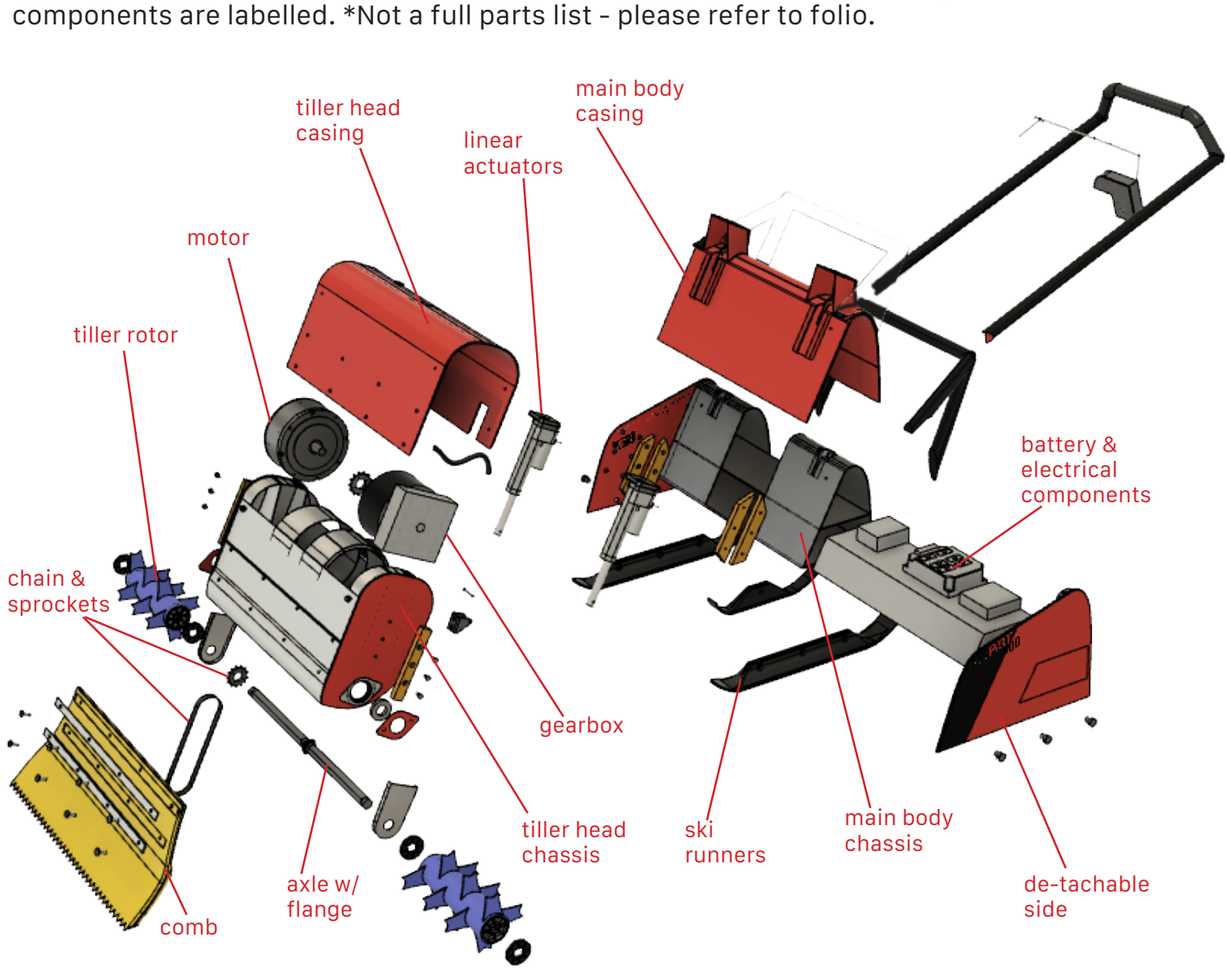
The user then moves to the next “strip' and repeats the process until the whole feature is shaped.

(DIS)ASSEMBLY

Due to the environment/context it is used in, the abuse it will undergo will inevitably lead to the replacement and service of parts. So, as well as having a very simple & intuitive control system, it has been designed to be extremely easy to maintain, service and replace parts. This ease of (dis)assembly also adds to the benefit of the machine not requiring a skilled user - Anyone can do it!

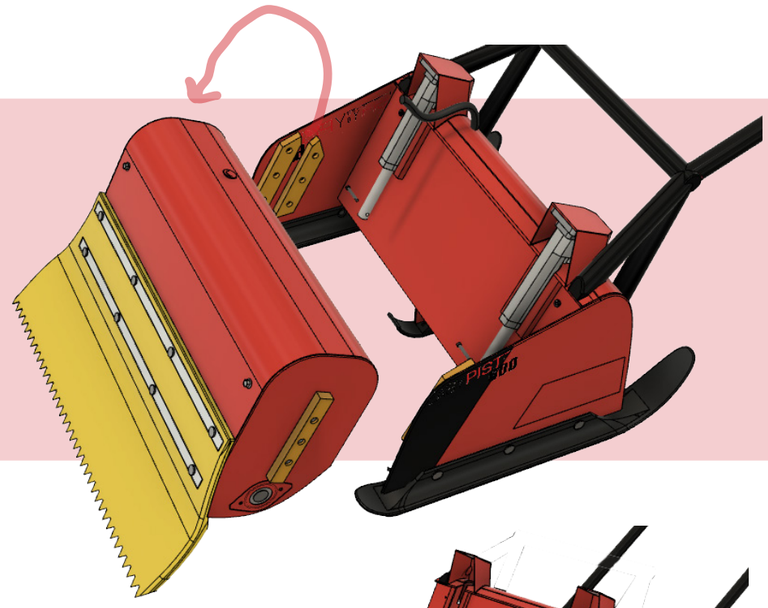
As well designing the obvious components such as the chain & sprocket casings which keep snow out, assembly has been considered down to the details. Some but not all of these details include: thermally/friction drilled holes for the bolts, chamfered guides to allow for the tiller head to be easily slotted back into the main body sides, graded steel bolts for the motor & gearbox housing, rubber cush drives to allow the tiller rotors to better withstand shock loads, the use of sealed roller bearings and a square & circular section axle to allow for efficient power transmission to the tiller.

This exploded view shows every part that is included in the CAD assembly. The main components are labelled. *Not a full parts list - please refer to folio.



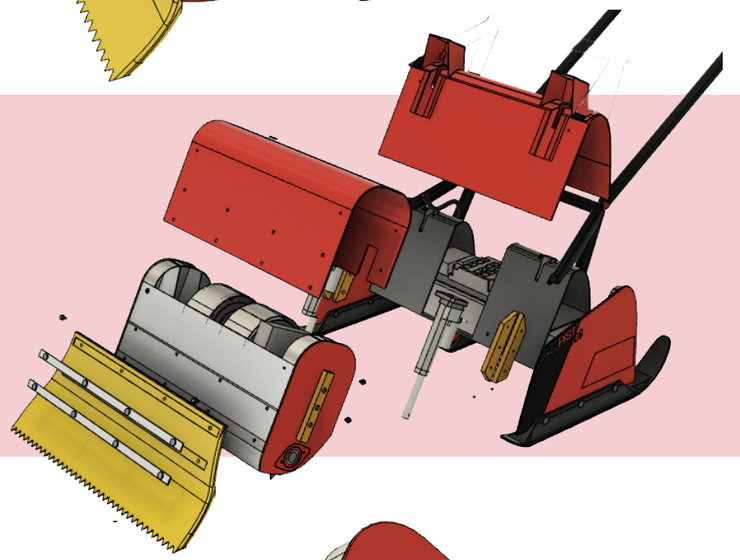
1

Separation of the two main bodies is extremely easy; the high IP rated power plug can be disconnected, the actuator bracket pins can be removed and the tiller head body can easily be lifted out of the guides/main body sides.



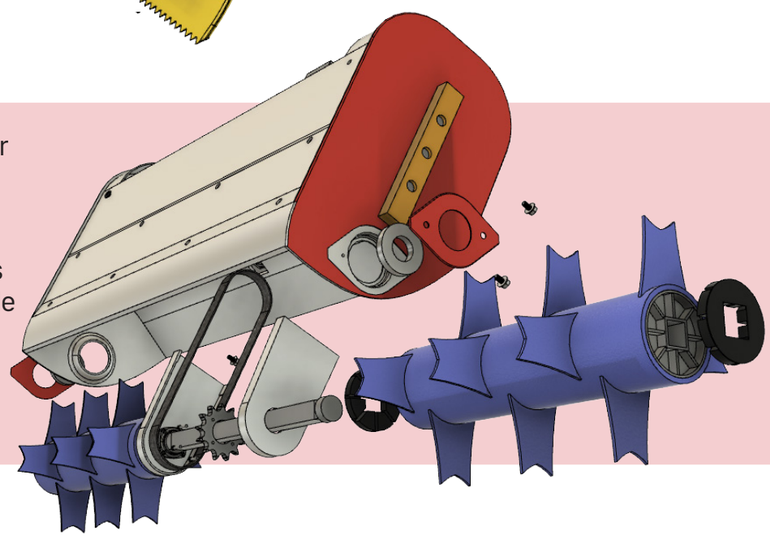
2

From here, bolts can be unscrewed and the casings can be lifted off the chassis'. The user then has access to the motor, gearbox, chain, battery and all electrical components within a few steps.
Ski runners, guides and the comb can also easily be dis-assembled through unbolting.



3

Through more unbolting, the tiller axle can easily be removed from its bearings in the tiller head chassis sides and taken down out of the chassis. From here it is extremely easy to unbolt and slide off the tiller rotors on either side for replacement if teeth become damaged. Sprockets are also easily detached & replaced.

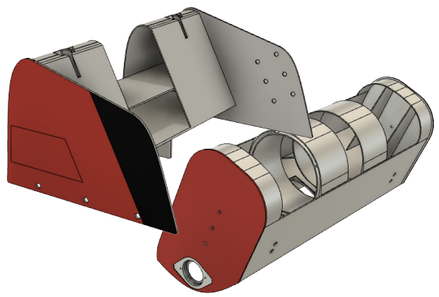


MATERIALS & MANUFACTURE

Material choice plays a big part in reducing the overall weight of the product. Weight was reduced by re-designing the bodies to be lightweight aluminium chassis' to support the structurally loaded parts only and even lighter weight HDPE casings for where no structural load is.

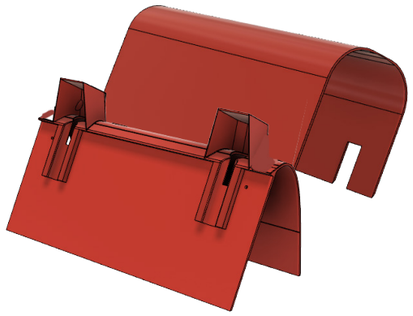
CHASSIS'

Material requirements were set out and aluminium was chosen due to its good strength to weight ratio and its ductility in low temperatures.



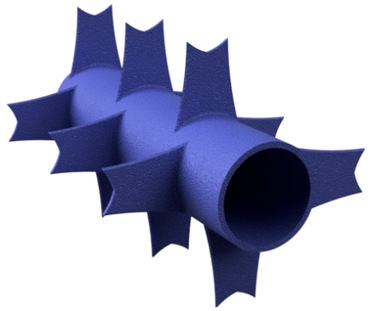
COVERS

HDPE was chosen for the casings due to its impact resistant properties as they need to be able to protect the chassis and main components from potential flying ice. It is also durable and resistant to corrosion and UV which is highly beneficial for this application.



TILLER

The tiller rotor is made from high grade steel as it needs to be extremely robust and durable to break through the ice.
The ductile-brittle transition temperature has also been considered here.

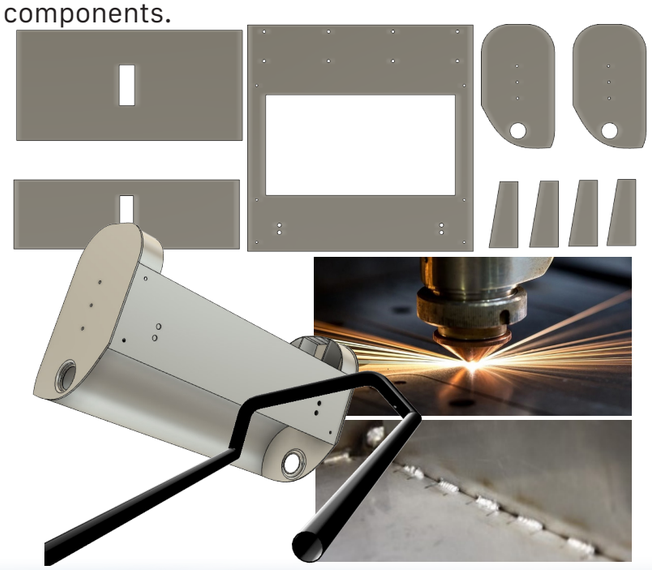


EXTRAS

The comb and block guides are made from flexible, impact resistant, vibration dampening, extremely smooth polyurethane which allows no snow to stick to it.
The skis have been inspired by snowmobile skis and so are made from UHMW Polyethylene to ensure smooth running.

MANUFACTURE

For the chassis', sheet metal will be laser cut, formed and manually stitch welded together with TIG. This process prevents heat distortion in the sheet aluminium. The small quantity of the products that are initially being made allow for cheap, simple & environmentally friendly processes to be used.
Other processes used include tube bending for the handle and heat forming for the plastic casings.
All materials will be finished with a non stick snow blower spray to prevent snow from sticking to components.



PRODUCT VALUES

- **AFFORDABLE:** Sold at a price of £4000 to target small ski resorts who will easily be able to afford it with it being a fraction of the price of a large piste basher. For a product that is doing a similar job, it is of great value.
- **LONG LIFESPAN:** The simple design and assembly mean a very long lifespan of the product. All main parts such as the battery, the chain, the sprockets, the bearings and the tiller rotors can easily be replaced every few years.
- **ROBUST:** The robust casing & chassis design of the product means that not much maintenance will be required, however if it is, it can easily be done by any user.
- **EASE OF USE:** The product does not require a skilled user. Therefore park features can be made safe, whatever the skill level of the park shaper. It is as simple checking the snowpack, pressing buttons and walking.
- **ENVIRONMENTALLY FRIENDLY:** With the product being battery powered and made from recyclable metals and thermoplastics, there is almost no negative envrionmental effect.
- **POTENTIAL:** The design has the potential to be sold at a range of sizes/powers - a smaller, lighter weight less powerful design could be made if necessary, as well as a larger heavier device with the potential for a drive to aid the pedestrian control.

PRODUCT SUMMARY

WHAT IS IT?

An all electric, hand operated, pedestrian controlled machine for grooming snow park features on a smaller scale. It's purpose is to do a similar job to a larger piste basher but in an affordable, more manoeuvrable and lightweight way. It is lightweight & manoeuvrable enough to be controlled easily by the human operator, but packs plenty power and weight in order to do an extremely efficient shaping job.

WHAT DOES IT DO?

The machine uses a high torque rotary tiller to break up and pulverise hard packed, un-shaped snow before using a snow finisher/comb to re-compact it, leaving an evenly shaped, pisted surface finish on the snow. The product can cater for all snow types through its use of tiller height adjustment. It is designed to groom out snow in the pull direction i.e. user pulling the tool to ensure an untouched finish.

HOW DOES IT DO IT?

A high performance Li-Ion battery provides power to a 3kw BLDC motor with 8:1 planetary gearbox. A chain drive transmits power from the motor to the rotary tiller with extremely high torque so it can break through any type of snow surface. The heavy weight of the tiller head and flexibility of the polyurethane comb ensure there is enough downward pressure to leave a smooth, even surface at all tilling depths.
Height adjustment of the tiller head is done through the use of 2 high force, synchronously controlled electric linear actuators. All adjustment is done "on the fly" through a simple, intuitive control pad at the handle.

WHY?

To provide an affordable and effective snow preparation tool for the smaller ski resorts who cannot afford or make efficient use of a large piste basher or small snow park shaper tool.

WHERE?

The product is aimed towards smaller ski resorts, for example Scottish ski resorts who do not need massive piste bashers for their small park features. Or cannot afford massive piste bashers - where they are a limited resource.