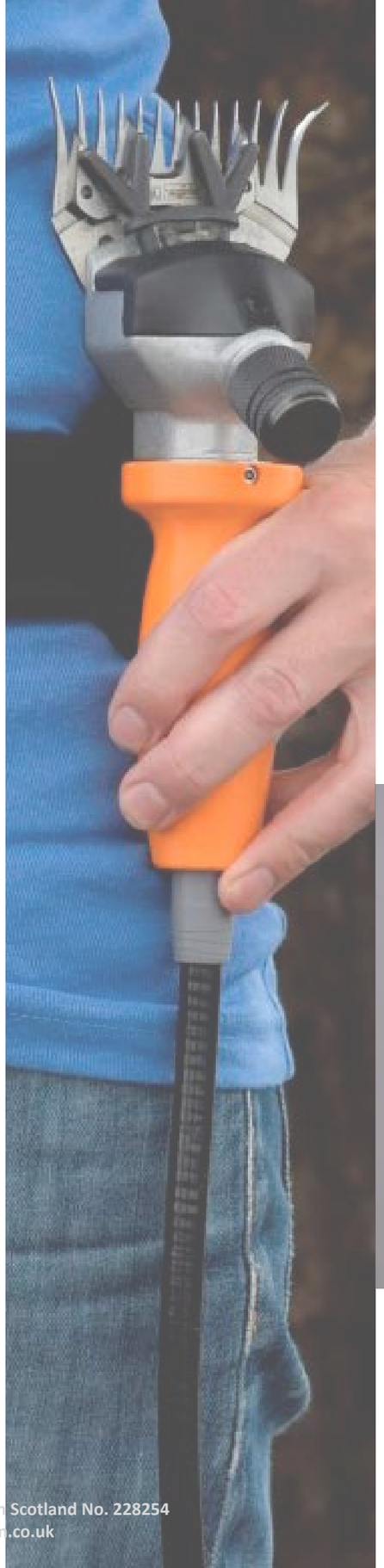
Smart Shearing Tool Summary

Australian Wool Innovation

4c Design

January - August 2020

Contents



Abstract

This report summarises the outcomes of our 'Smart Shearing Tool' project. Research, concept generation and prototyping processes took place, and this report details the final stages of work following this development.

We present the final prototypes of this body of work, as well as the outcomes of our testing. This will include a pre-comb design with integrated sensors that will allow for a consistent distance to be maintained from the skin of the animal, as well as a belt-mounted power and motor system that allows for freedom of movement away from the restriction of the downtube.

The commercial development and stakeholder interest in our concepts has also been considered, and contact made with both Senesino (the company responsible for the distribution of Numnuts) and a global distributor of shearing equipment.

The final evaluations and next steps of this project will also be documented, detailing further testing and trials that would be beneficial for the development of this project

- **paving the way for automation**.

Project Overview

This project initially started with extensive research both in Australia and the UK. It was important for us to gain an understanding of the problems shearers faced from speaking to them directly, and also observing their work.

It was from this research that we were able to build our requirements for this project. We limited our focus to three main areas:

Maintaining a consistent distance from the skin. This was something that would de-skill the shearing process, both helping to reduce skin cuts on the animal, and allowing wool growers to get the most consistent staple length. **Removing the requirement for the downtube.** This would reduce the requirement from for woolgrowers to provide large infrastructure for shearing, and would open up the possibility of not having to move sheep so far to the shearing shed. More importantly, it would reduce the amount of animal handling required, which would be beneficial for both the health of the shearer, and the comfort of the animal. Finally, we looked at **reducing the skill of maintenance.** Using sharp gear makes the job easier, and knowing when to change the combs and cutters can take years of experience.

With these requirements in mind, work began on developing a device that could run from a belt mounted drive system, while keeping the body and weight of the handpiece itself small. Work also went into developing a 'pre-comb' that would help to maintain a consistent distance from the skin, while integrating sensors that would help the shearer to keep the handpiece level. Finally, the motor and power system used to drive the device have the potential of indicating that the gear is blunting and requires maintenance.

This report details the outcomes of the previous months of development, showing the final prototypes and testing outcomes of these designs.

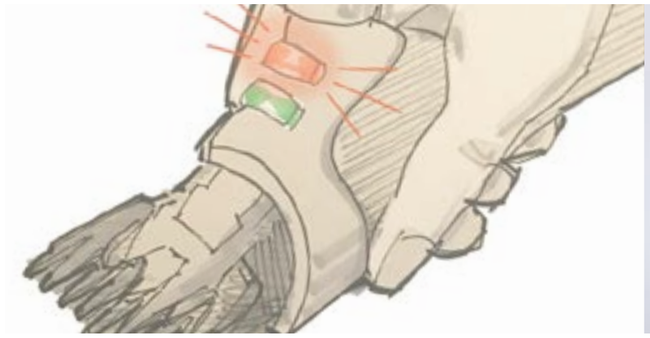
Sensor Prototype

Throughout the project we have been looking to address some of the compromises faced by shearers using traditional equipment. During our research phase we realised quite quickly the technology of both the handpiece and the drive system had not moved on considerably in decades. Small improvements had been introduced throughout that time, including developments in materials and safety.

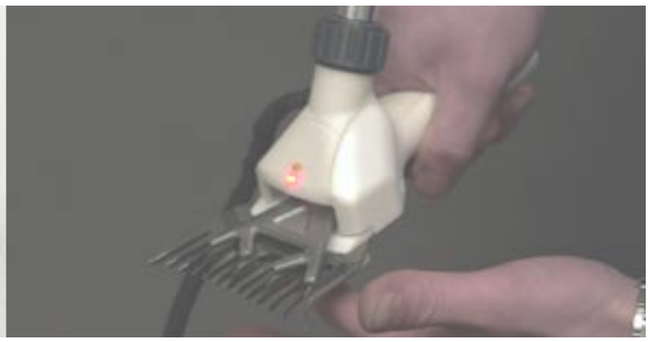
Our ambitions centred around de-skilling the process, while also considering animal welfare. This lead to us introducing new technologies, such as sensors and protective comb covers to assist the user and quickly build up confidence. The prototyping of these components gave us a good idea of how important the skilled set-up of the handpiece was, and how sensitive it was to additional features. Early tests with plastic ‘pre-combs’ didn’t perform well and required us to rethink our approach. This has lead to a new round of prototyping, which features a more compact pre-comb.

This sensor prototype performs well on human skin, and can differentiate between this and wool, but in order to confirm the success of this design, it would need to be tested on the skin of a sheep. It is possible that fine tuning may be required, depending on dust/ moisture levels on the skin, which can not be confirmed until further testing is carried out. Unfortunately due to COVID 19, this testing has not been possible, but testing this comb in isolation on an existing shearing handpiece should pose no risk to the animal.

The motor we are using could have the ability to sense when the gear is beginning to blunt. This could then alert the shearer, enabling only the sharpest most efficient cut, reducing stress and strain on both the shearer and the animal.




4c Design Ltd. R13, 100 Borron Street, Glasgow, G4 9XG, Registered in Scotland No. 228254
0141 353 5490 info@4cdesign.co.uk www.4cdesign.co.uk
4c Design Ltd. R13, 100 Borron Street, Glasgow, G4 9XG, Registered in Scotland No. 228254
0141 353 5490 info@4cdesign.co.uk www.4cdesign.co.uk

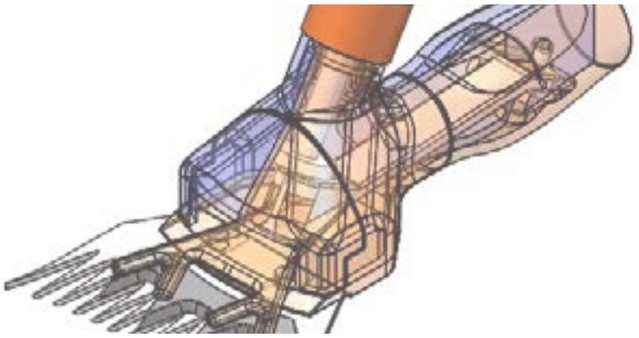
New Mechanism Prototype

A new mechanism was developed that would allow the drive shaft to travel down the arm of the shearer and join the device where the cutter tensioner sits. This would also help to take some of the weight of the device, as the drive shaft would be above the handpiece rather than behind it.

Further testing with this new design would need to take place, gaining feedback from shearers, as there are concerns that it may restrict movement when rotating the handpiece around the contours of the animal.

This new mechanism was also designed to sit within a much smaller body than the traditional electric handpiece. This allows for a much more ergonomic form that is more easily used for longer periods of time, rather than the usual crutching applications of the electric handpiece.

The quick return mechanism converts the rotational motion from the drive shaft to a reciprocating motion for the cutter. It runs directly from the drive shaft, and operates with a cam running in a slot, moving the cutting arm from side to side. Further development would need to take place around tensioning this mechanism, but in this current setup the cutter runs back and forth along the comb when the 'drive shaft' is rotated.



4c Design Ltd. R13, 100 Borron Street, Glasgow, G4 9XG, Registered in Scotland No. 228254
0141 353 5490 info@4cdesign.co.uk www.4cdesign.co.uk

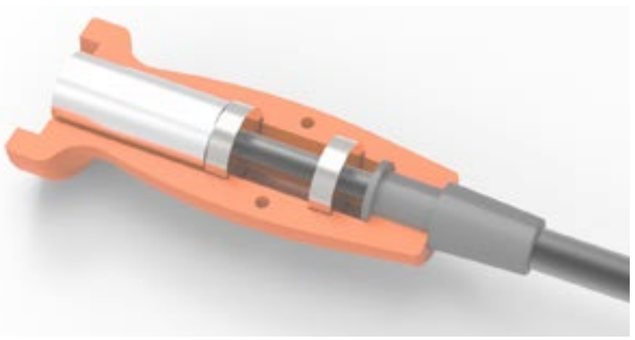
Drive Train Prototype: Handpiece

The idea behind introducing a new drive train for the handpiece was first suggested early on in the project, but was considered to be potentially be outside the scope of the contract. However, once we started to review the handpiece in detail and consider the features required to give feedback to the user and bring a more ergonomic feel to the unit, it was clear that upgrading the entire system would be a benefit.

From early discussions at the AWI offices in Sydney, we established that giving the shearer more degrees of freedom and not restricting them to a fixed shearing station may be a real benefit to the industry. With this in mind it was logical for us to explore the very best case scenario, where the shearer has complete independence and can take the shearing to the sheep. This would not only reduce the stress on both user and animal, but also remove the need to lift or drag sheep to a fixed point - a known cause of back trouble.

A modified electric shear was created, allowing a flexible drive shaft to be attached directly to the back of the handpiece. This was a slimmed down version of a prototype from previous iterations, as we were aiming to make the body of the handpiece comparable to a traditional handpiece, rather than an electric handpiece.

The drive shaft is clamped within the grey component, shown in the cross section below, while multiple bearings help the shaft run as smoothly as possible.



4c Design Ltd. R13, 100 Borron Street, Glasgow, G4 9XG, Registered in Scotland No. 228254
0141 353 5490 info@4cdesign.co.uk www.4cdesign.co.uk

Drive Train Prototype: Motor

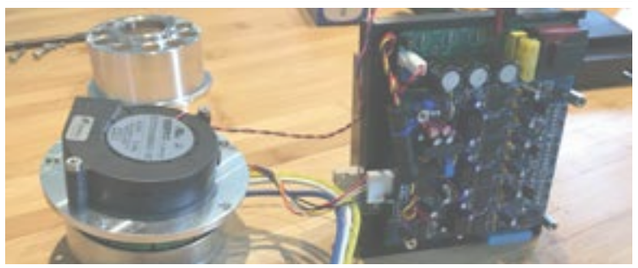
The belt-mounted drive system of this handpiece was developed, including a motor, battery and motor controller.

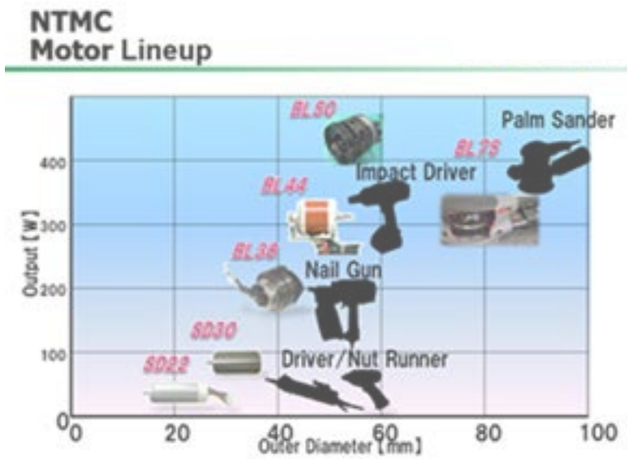
A great deal of research went in to sourcing a motor that would provide the same performance as the static mounted Heiniger EVO units (used as a benchmark), but at a fraction of the size. The motor finally selected for this task was a brushless (BLDC) motor. This motor will run quietly and will only use a percentage of its full capability, which will in turn contribute to its reliability.

These motors are lightweight and relatively inexpensive, meaning they are suitable from a usability and commercial standpoint. Once selected the motor was ordered and a coupling designed to allow us to connect a drive cable.

We have been experimenting with the orientation of the drive cable and are currently trying a different configuration to see if we can reduce stresses on the cable itself as it runs the handpiece. This will become more of an issue when the unit is considered for trials on real animals, but is not an important consideration at this point of testing.

We noticed during initial trials, the motor tended to 'kick' when started, which is a common phenomenon with high powered devices. This means we have incorporated a manual 'soft start' by means of a rotary selector that can be turned down low for starts and stops. This would be something we would incorporate into a future development that happens automatically.





4c Design Ltd. R13, 100 Borron Street, Glasgow, G4 9XG, Registered in Scotland No. 228254
0141 353 5490 info@4cdesign.co.uk www.4cdesign.co.uk

Test Methodology

We are working to a simple test methodology table to ensure that none of the technology we are introducing compromises the entire system. As we have been unpacking and reviewing the components and sub-assemblies, we tested the parts individually, following the test methodology below.

Battery
Batteries were charged and voltage tested to ensure they were in good health. All connections were checked before linking them to the motor controller and motor. Two batteries were supplied to ensure we could run a long term test without waiting for batteries to charge in between.

A duty time test will be carried out in due course to establish how long the batteries last in the field.

Motor
The motor was selected for its power to weight ratio coupled with availability and cost. This particular unit will only ever run at a low percentage of its capability, therefore will be more reliable in the field. Testing comprised of starting and stopping the unit, before coupling it up to anything.

Controller
The controller is an 'off the shelf' unit, which means it comes having already been tested, was available to purchase quickly and will perform reliably as a result. For future consideration a more bespoke unit would be employed, because this current unit has much more capability and functionality than we will ever require.

Description	Test	Linked to	Sub-system	Full System
Battery	Voltage and Integrity	Motor Controller	Check Yes/No (repeat)	Cleared
Motor	Mechanical and Power	Controller and Drive Cable	Check Yes/No (repeat)	Cleared
Controller	Signal and Operations	Battery and Motor	Check Yes/No (repeat)	Cleared
Drive Cable	Integrity and Connections	Motor and Handpiece	Check Yes/No (repeat)	Cleared
Handpiece	Cutter Set-up and Integrity	Drive Cable and Sensors	Check Yes/No (repeat)	Cleared
Sensors	Wiring and Accuracy	Handpiece	Check Yes/No (repeat)	Cleared

4c Design Ltd. R13, 100 Borron Street, Glasgow, G4 9XG, Registered in Scotland No. 228254
0141 353 5490 info@4cdesign.co.uk www.4cdesign.co.uk

Complete System Testing

Drive Cable
As we have adapted the drive cable to suit our application it is important this is tested independently of the complete system to ensure we have not compromised its integrity, which could have performance consequences with the other equipment.

As mentioned before in the report, the orientation of the cable could affect the performance and usability of the assembly, so trials of each configuration will need to carried out.

Handpiece
The prototyped handpiece to be used in conjunction with the drive train has been assembled and tested using a cordless drill. This has sufficiently tested the overall integrity of the unit, but once coupled up with the drive train, we noticed high frequency vibrations through the body of the handpiece.

We are able to use the current assembly for quick trials (and to satisfy the content of this report), however the design will need some further tweaks and prototyping longer term.

Further successful tests were carried out on the wool samples using an off the shelf handpiece to test the integrity of the drive train system.

Sensors
The testing of sensors will only really be relevant on actual sheep trials, but the infrastructure supporting them has been tested and incorporated into a semi-functioning handpiece to see if their integration causes any issues with space and usability.

Due to their size and low power, they do not pose any risk the rest of the assembly.

The test results can be seen below:

Description	Test	Linked to	Sub-system	Full System
Battery	Voltage and Integrity	Motor Controller	Check Yes/No (repeat)	Cleared
Motor	Mechanical and Power	Controller and Drive Cable	Check Yes/No (repeat)	Cleared
Controller	Signal and Operations	Battery and Motor	Check Yes/No (repeat)	Cleared
Drive Cable	Integrity and Connections	Motor and Handpiece	Check Yes/No (repeat)	Cleared
Handpiece	Cutter Set-up and Integrity	Drive Cable and Sensors	Check Yes/No (repeat)	Not cleared for long-term use
Sensors	Wiring and Accuracy	Handpiece	Check Yes/No (repeat)	Cleared

The independent technologies being developed by the team at 4c Design have been tested and we are happy the complete assembly is fit for initial trials. We have some concerns over the 'long term' use of the modified handpiece and will address this, but are still confident that we can use the device to shear our fleece samples.

Mounting the components on the padded belt and walking around with it on will determine whether the shearer can realistically carry the battery, motor and handpiece on their body as they move from animal to animal. Initial trials of this are proving very positive and it feels like a good balance has been achieved.

It is not clear at this point just how much more weight we might be able to remove going forward, but we are very confident that improvements can be made.

The unit has been tested on a lightweight belt strap, which on first impressions felt loose and uncomfortable. The handpiece itself also felt like it had a lot of vibration running through it, which was caused by some of the prototype materials, but also the sheer power of the drive system.

We have since moved to a padded belt and have made a few small corrections to the mounted parts to improve the feel and performance.

As can be seen from the images on this page, the system is a vast improvement in versatility and size over the existing static shearing stations, but further development is definitely required to ensure that the kit can be carried for the duration of a shearers shift, without compromising welfare and that the motor and drivetrain have the robustness to deliver the results required.

From initial tests and usability trials, the kit feels advanced and efficient, while allowing the shearer lots of freedom to manoeuvre around the sheep he or she is shearing rather than wrestling with the animal to keep it firmly positioned in one spot.

4c Design Ltd. R13, 100 Borron Street, Glasgow, G4 9XG, Registered in Scotland No. 228254
0141 353 5490 info@4cdesign.co.uk www.4cdesign.co.uk
4c Design Ltd. R13, 100 Borron Street, Glasgow, G4 9XG, Registered in Scotland No. 228254
0141 353 5490 info@4cdesign.co.uk www.4cdesign.co.uk

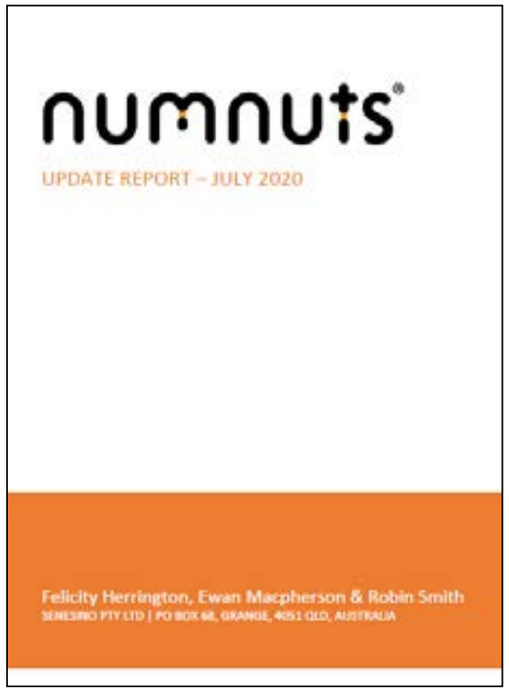
Commercial Development

At the point of writing, both Senesino and a global leader in shearing equipment have been approached to review the design of the new system. Both have shown a great deal of interest in the work we have been doing with AWI. Senesino have some very relevant 'front line' experience of bringing novel technology to market.

4c Design established the 'spin-out' company, Senesino Ltd. in 2017 in order to focus upon the business process of product development and commercialisation. In the first instance Senesino has taken 'Numnuts®' – simultaneous ring application with local anaesthetic injection for the marking of lambs – forward into the Australian market, launching the product at the AVA conference in Perth W.A. in May 2019. A subsidiary company Senesino Pty Ltd. (ABN 40633849779) was established, a director re-located to Australia, and distribution channels via vets for the Schedule 4 local anaesthetic component 'NumOcaine®', and directly to farmers and end-users for the hardware components, via an on-line shop – www.numnuts.store. This direct contact with end-users has proven invaluable in building and maintaining direct relationship and feedback and has contributed to the rapid sales growth now resulting.

Senesino Pty Ltd. currently has two employees in Australia supported by two staff in Scotland, and works with a range of industry partners across Australia. Plans are at an advanced stage to launch Numnuts® into New Zealand for 2021 (postponed from 2020 due to Covid-19 restrictions). Senesino Pty Ltd. is also involved in two future development projects in connection with Numnuts® with partners in Australia and New Zealand. Senesino Ltd. is working with partners in Europe towards the introduction of Numnuts® into this market (where regulations are different from Australia). Senesino and 4c Design are working together on the technical aspects of other new product innovation in the agricultural area works, in particular animal health and welfare. Both companies could provide a commercialisation route for the new shearing design, but further development is required on the device. This will require investment and therefore a consideration has to be made about who could help support with that going forward.

It is recommended that a commercial development plan is established with AWI, before any further discussions happen with future partners. This will not only clarify what the business model for the device looks like, but also help us identify intellectual property worth protecting.



4c Design Ltd. R13, 100 Borron Street, Glasgow, G4 9XG, Registered in Scotland No. 228254
0141 353 5490 info@4cdesign.co.uk www.4cdesign.co.uk

Stakeholder Review

The design of the handpiece and subsequent infrastructure has been heavily influenced by our research, both in the UK and in Australia. Our intention was to re-engage with some of the people we spoke to and to document their feedback in an attempt to validate many of the decisions we have made around the design. The stakeholders involved include industry experts we met in Australia and some of the users and sheep farmers based in the UK.

At the time of writing further restrictions have been introduced, limiting travel and social interactions. Due to the nature of the product and the fact that using the product is the single best way to provide feedback on the performance, we have been unable to revisit those contributors who helped with our initial research.

We are still confident that we will be able to re-engage with a shearer we spoke to earlier in the year, who was keen to assist with the prototyping review, but this feedback will need to be arranged for a future date when restrictions are lifted. We are very keen to bring someone in who has had experience with the existing shearing equipment, and can fully appreciate the technology shift that the belt mounted system is offering. It is also important for us to hear about the potential shortcomings of this equipment as we consider how to move the design forward.

The point of stakeholder reviews is to establish a better understanding of the problems still needing addressed as well as ensuring we are indeed moving the product forward in the right direction. It is always desirable to identify as many issues at the early stages of prototyping as possible. This ensures that larger and more costly mistakes are potentially avoided at a later date.

4c Design Ltd. R13, 100 Borron Street, Glasgow, G4 9XG, Registered in Scotland No. 228254
0141 353 5490 info@4cdesign.co.uk www.4cdesign.co.uk

Conclusions

For this report we have highlighted the actions undertaken in July to build and test the complete system we have designed to ‘modernise’ the art of shearing. The design journey has been influenced by the research carried out in Australia at the beginning of 2020 and despite some restriction on our working practises due to the outbreak of COVID-19, we have managed to run a comprehensive design project.

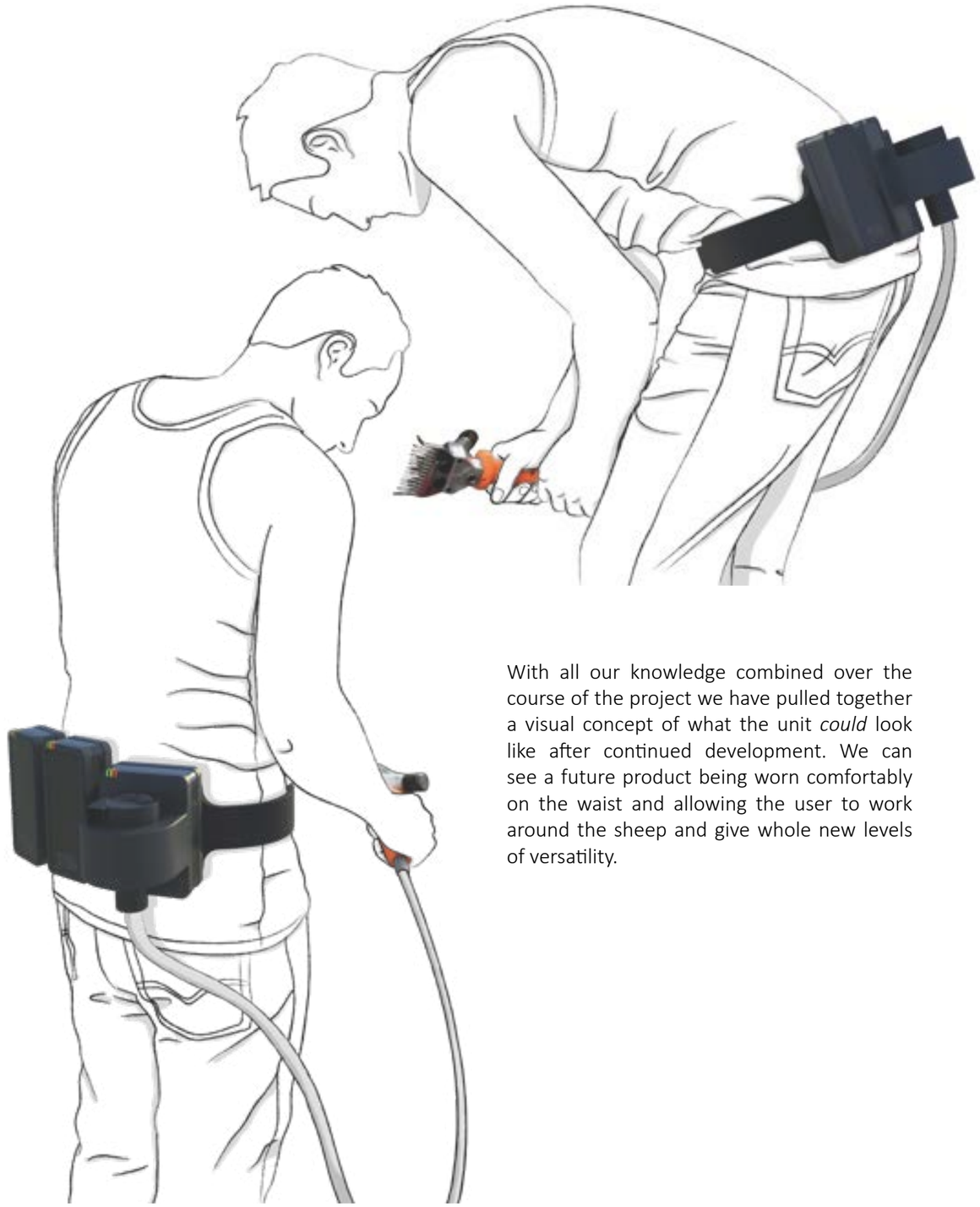
In our original discussions with AWI we proposed breaking the project down into smaller technology developments with the aim of eventually working with AWI again to visit the possibility of a fully automated shearing robot. Given the current equipment has only seen minor upgrades over the last 75 years, we felt reviewing the handpiece was a perfect place to start. This is what formed the basis of the project covered in these reports.

While we could see what modifications could benefit the user and animal, we quickly understood the restrictions of the overall infrastructure behind the handpiece. Due to the size of the motor, the only option was to have this mounted in a fixed location. It also lacked any form of electronic control, meaning the speeds were determined by mechanical pulleys and no smart technology could be integrated.

By sourcing a motor (with controller) of equal performance, but a fraction of the size, we were able to explore suitable data recording technology to help inform the user and the device how the shearing was progressing. The new motor controller we have sourced for example has the potential to tell the operator when the gear on the handpiece is blunting. This type of information can be very valuable for making sure the equipment is kept in good condition and as a result ensuring an efficient cut.

From the results of our tests, we are confident that this new equipment concept will help bring shearing into a new technology age, which in turn should help attract a new generation of shearers to the job.

Product Concepts



With all our knowledge combined over the course of the project we have pulled together a visual concept of what the unit *could* look like after continued development. We can see a future product being worn comfortably on the waist and allowing the user to work around the sheep and give whole new levels of versatility.

4c Design Ltd. R13, 100 Borron Street, Glasgow, G4 9XG, Registered in Scotland No. 228254
0141 353 5490 info@4cdesign.co.uk www.4cdesign.co.uk

Evaluations and Next Steps

The equipment we have developed will require some longer term tests. As we have stated in previous reports, the prototypes have only been designed to be tested on fleece samples, constructed in our own workshop. This means that testing on live animals will require consultation with AWI and other stakeholders before fully understanding the requirements.

We are however confident that our approach to the design of a smart shearer has shown a great deal of potential and as a result could inspire a complete technology shift in shearing. This kind of development not only has a short term potential to improve the shearing experience for both user and animal, but also starts to pave the way for automation.

4c Design Ltd. R13, 100 Borron Street, Glasgow, G4 9XG, Registered in Scotland No. 228254
0141 353 5490 info@4cdesign.co.uk www.4cdesign.co.uk