FINAL REPORT

Lamb Frenching

Final Report

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PREPARED BY:	Merv Shirazi
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1.0 EXECUTIVE SUMMARY

The overall objective of this project is to design, build, develop, install and trial an automated system for french dressing lamb ribs. This will be a prototype system, which will run limited trials at an agreed host site most preferably in Scott NZ Christchurch facilities.

Manual frenching of lamb racks requires skilled knife-work and consumes considerable labour resources. Current commercial frenching solutions (that require reduced labour) result in significant water (and noise) pollution, result in a loss of valuable intercostal meat and produce a waste stream of a lamb stew broth that then requires treatment.

Various companies in the past (including Scott) have attempted to semi-automate or automate the lamb frenching process. Non-water (waterless) developments (by Scott and others) have not been successful due to the application of either tactile or non-x-ray vision or sensing systems. They work, however the yield recovery and final presentation is not acceptable.

In this project Scott Automation and Robotics have applied their automation knowhow into developing an automated solution that uses a machine to automatically french lamb racks without the downsides of current water frenching solutions.

As one of the first approaches, Scott planned and trialed a series of CO2 jet knife concept to remove meat from bone but the concept was not viable due to high capital investment and not recovery of intercostal meat.

The next approach was to try mechanical approach. It was believed that if somehow ribs are sensed then a loop around a rib, pulled with force, could remove the intercostal meat and leave the rib appropriately clean.

Figure 1: Testing Intercostal Removal Hypothesis

This workshop test was developed into a test mechanism, and ultimately the proof of concept system that was trialled at the host processor site.

The test mechanism used two rows of slotted needles to capture the tensioned braided lines. As the top and bottom rows of needles are pushed towards each other, the tensioned braided lines are pulled through the intercostal, creating a loop around each rib.

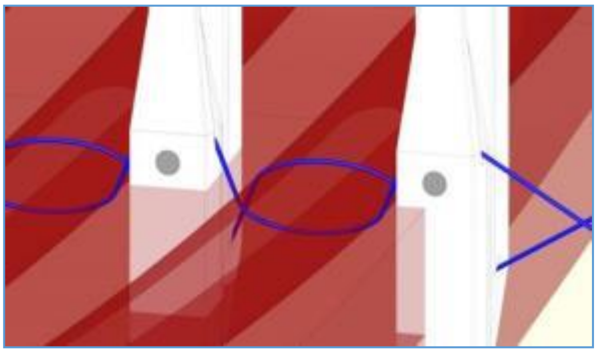


Figure 2: Theoretical Method of Intercostal Removal

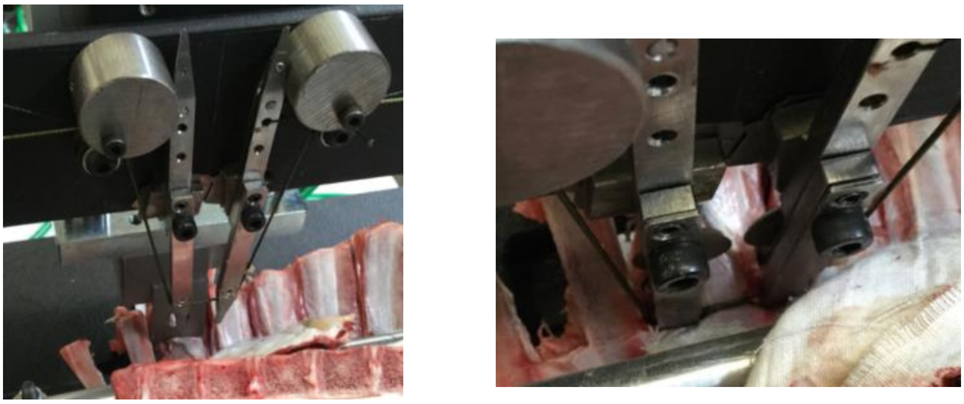


Figure 3: Test Rig used during Mechanical Concept Design

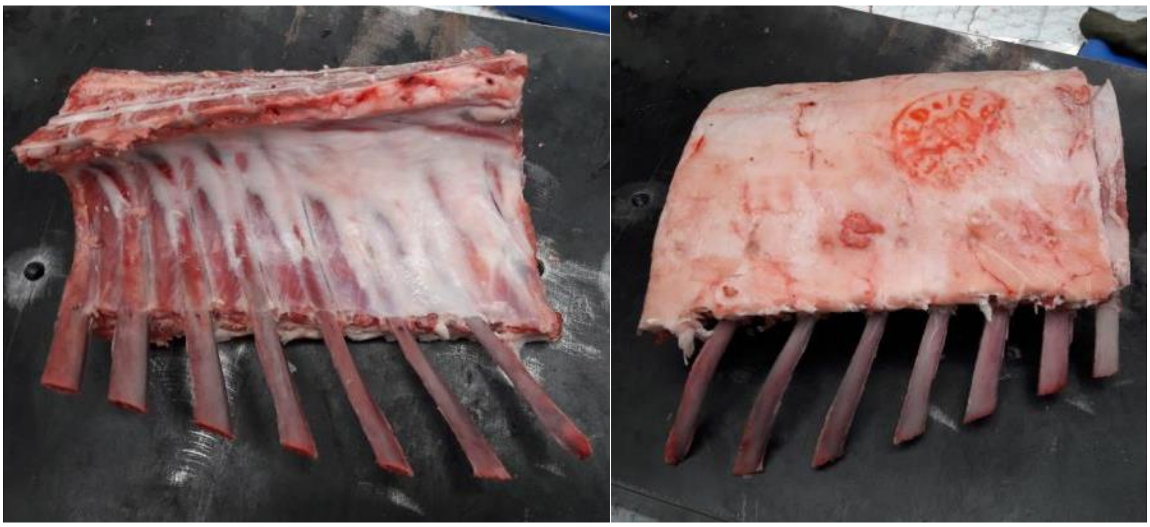


Figure 4: An example of the results achieved with the prototype

At the completion of this project two things have been developed:

- A primal specific small footprint machine for application to lamb frenching (and possible modular platform extension to lamb primal automation in the future).
- A waterless lamb frenching solution prototype for installation and demonstration within an Australian processing facility.

Whilst the prototype sufficiently demonstrated the proof of concept, there are a number of issues to be considered during the next phase of the project. These include:

- Meat to be recovered in the form of intercostal
- System to be designed to handle 10 rack a minute
- Current rib surface finishing is acceptable but there are some room for improvement
- Determine durability of the wire, type and material in wire
- Determine how often the wire needs to be cleaned, introduction of cleansing process for wire to clean up the excess fat, perhaps a bath/hot water tank or a contact/friction/brush cleaning mechanism.
- Wire change procedure
- Longevity of rotary blade and sharpness

2.0 INTRODUCTION

Manual Frenching of lamb racks requires skilled knife-work and consumes considerable labour resources.

Current commercial Frenching solutions (that require reduced labour) result in significant water (and noise) pollution, result in a loss of valuable intercostal meat and produce a waste stream of a lamb stew broth that then requires treatment.

Various companies in the past (including Scott) have attempted to semi-automate or automate the lamb Frenching process. Non-water (waterless) developments (by Scott and others) have not been successful due to the application of either tactile or non-x-ray vision systems. They work, however the yield recovery and final presentation is not acceptable.

This project would result in Scott applying their automation and x-ray/sensing knowhow into developing an automated solution that would use x-rays and a machine to automatically French lamb racks without the downsides of current water Frenching solutions.

At the completion of this project two things will have been developed:

/ A primal specific small footprint machine for application to lamb frenching (and possible modular platform for extension to lamb primal automation system in the future).

/ An X-ray / Sensing enabled waterless lamb Frenching solution prototype for trials and demonstration within a Lamb processing facility.

After this development it is plausible that Processors could participate in a PIP to have a commercial prototype developed for their business. It is anticipated that the R&D prototype from the current project would be relocated to each Processor's facility for evaluating as part of the PIP process.

This report details the investigations, design and development, testing and evaluation undertaken in producing the Proof of Concept for Lamb Frenching System. The prototype was used to french ribs at a host processing site, Allied Meat Processing in Timaru, and a demonstration was held for stakeholders from AMPC, MLA, JBS and ALC and Scott Automation and Robotics.

3.0 PROJECT OBJECTIVES

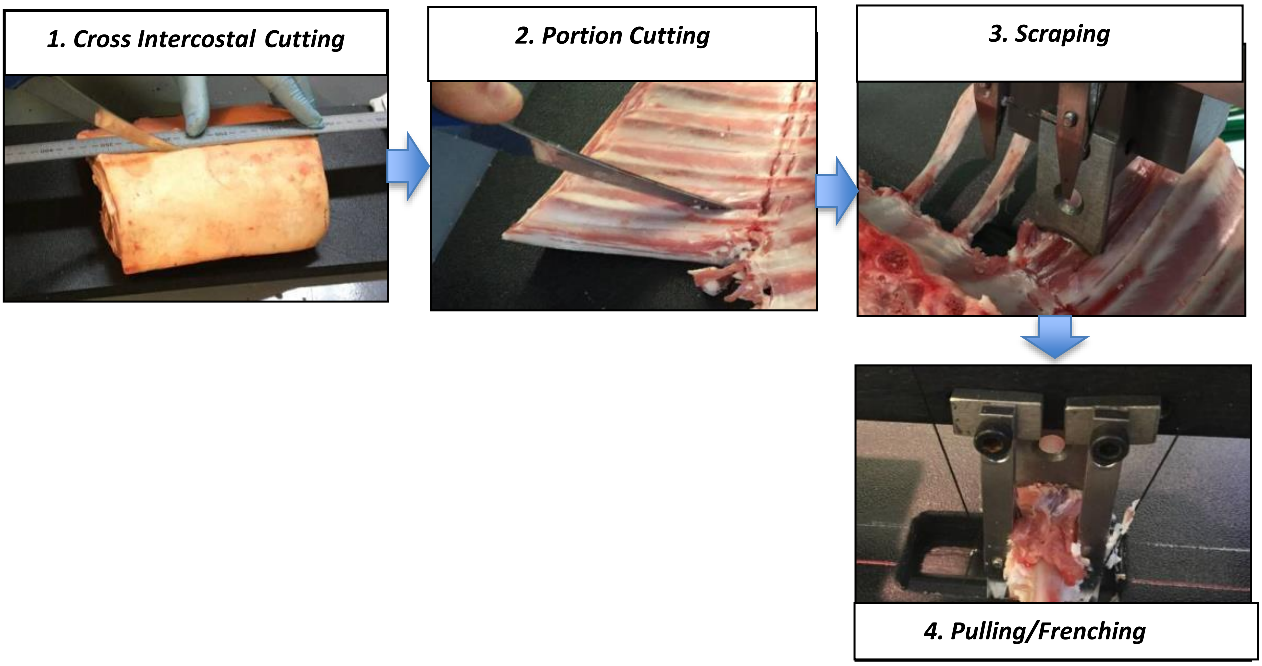
The overall objective of this project is to design, build, develop, install and trial of a proof of concept automated system for Lamb Frenching. This will be a prototype system, which will run limited trials at an agreed host site.

It should be noted that when this project commenced, work on several of the milestones was begun concurrently. Initial x-ray/sensing trials were carried out, the design concepts were reviewed and mechanical testing was carried out. The design team believe that they can design and build a machine that may not require x-ray technology. Hence, a better methodology is to perfect the mechanical design and then add the sensing and x-ray components as required.

A variation was submitted to, and approved by, AMPC. The order of the milestones has been rearranged. Milestone 1 now comprises all of the concurrent work that was completed in reaching the Stage 1 Mechanical Concept design. Milestones 2 to 5 are the mechanical investigations and prototype build. Milestones 6 and 7 are x-ray and sensing evaluation and implementation. Milestones 8, 9 and 10 are site trials and final report.

3.1 Mechanising Frenching Process Steps

There are four process steps to be mimicked by the frenching system. They are:



4.0 MECHANICAL CONCEPT DESIGN

Initially, the concept for the mechanical design had to be determined through a range of trials in order to assist towards the end design.

4.1 Investigating Methods of Scribing and Intercostal Removal

In order to remove the meat between the bones, aforementioned meat is required to be initially scribed to create stress points and allow the meat to be easily freed from the bone. The force was required to be found that is need to cut through the sinew to the lamb rib bone, and a test rig was created in order to acquire this information.

Figure 5: Test Equipment

Figure 6: Boning Knife

Figure 7: Scraper Blade

Figure 8: Jug used to apply extra load

The scribing was tested with both a boning knife and a scraper blade, and the lamb ribs were scribed with varying amounts of force, which was added through adding water to the jug.

Figure 9: Rack #1

Figure 10 – Pre-Cut Split Point Rack #1

Once scribed, the rack was placed inside the test rig to pull the intercostal and remove the meat from the rib bones. The force was then measured that it took to remove the intercostal.

Figure 11: Single Monofilament Noose

Figure 12: Nylon Braid with Fixed Loop

Figure 13: Sinew remained on single scribe removal

Figure 14: Load for Intercostal removal

The results of the tests are shown below.

Figure 15: Results – Scribed Side (LH to RH)

Figure 16: Single Scribe (three ribs on left)

Figure 17: Double Scribed (two ribs in center)

Figure 18: Scraper Cap Side (three ribs on right)

Concurrently with the sciribing testing, there were methods of removing the intercostal tested. The conclusion was that a braided fishing line that was chocked with a cable tie yielded almost a perfect result.

Figure 19: First rib using cable tie method

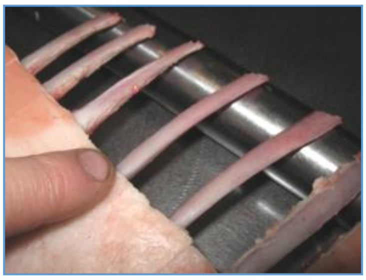


Figure 20: Cable tie method result (rib adjacent to and below finger)

4.1 Further Trials into Intercostal Removal

Another test rig was put together in order to perform trials into how to remove the intercostal, to attempt to evolve the trials further towards the final solution.

Figure 21: Closing Mechanism onto Rack

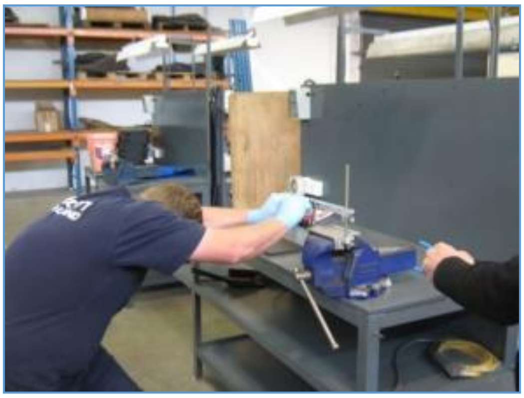


Figure 22: Pulling of Intercostal from Test Rig

Figure 23 – Intercostal being removed

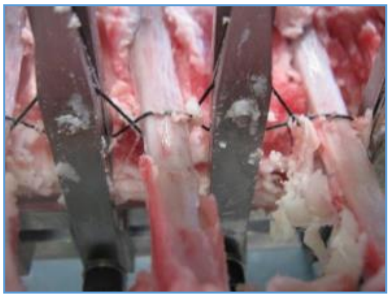


Figure 24: Braid not fully encompassing rib

A range of different methods of removing the intercostals were applied, and it was concluded that :

- The ribs must be scraped and the intercostal/eye muscle split point must be processed prior to using the braided line pull method.
- Trying to remove the intercostal whole requires significant force even when frenching only 5 ribs of a possible 9. The force has to be accompanied by a side shift movement to allow each rib to begin to pull away.

Further testing indicated that for a clean and consistent french, initially cutting the intercostals was the best option- with the conclusion that it was done best through the use of a rotary blade.

5.0 RIB POSITION SENSING

Initial design dictated the requirement of an X-Ray machine in order to determine the positions of bones within the rack of lamb ribs. This was due to the inability to accurately find the bones through colour or depth imaging. Throughout the trial process, the idea of using a measurement scribe was tested and validating. This essentially finds the peaks and troughs of a reacting force against a scribe as it tracks across the lamb ribs. This is a positive impact of the whole project because it provides reduction in the following areas:

- Cost - Without the need for x-ray components and shielding, the overall cost of the system is reduced
- Weight – The x-ray source, detector and shielding are no longer present and their associated weights are void
- Design complexity – X-ray image processing is not necessary and the mechanical design no longer requires shielding.
- Maintenance - Associated with x-ray tubes, detectors and electrical are not present
- Safety risk – Radiation is no longer present and therefore this will mitigate radiation leakage risk.

As a result the initial scribe also is used to find the positions of the bones, where the force is measured normal to the axis of the rib.

6.0 FRENCHING SYSTEM PROOF OF CONCEPT FINAL DESIGN

As discussed earlier there are four processing steps that must be carried out. The following in-line proof of concept system will perform the required processing steps. The lamb rack will move through the system shown below from left to right.

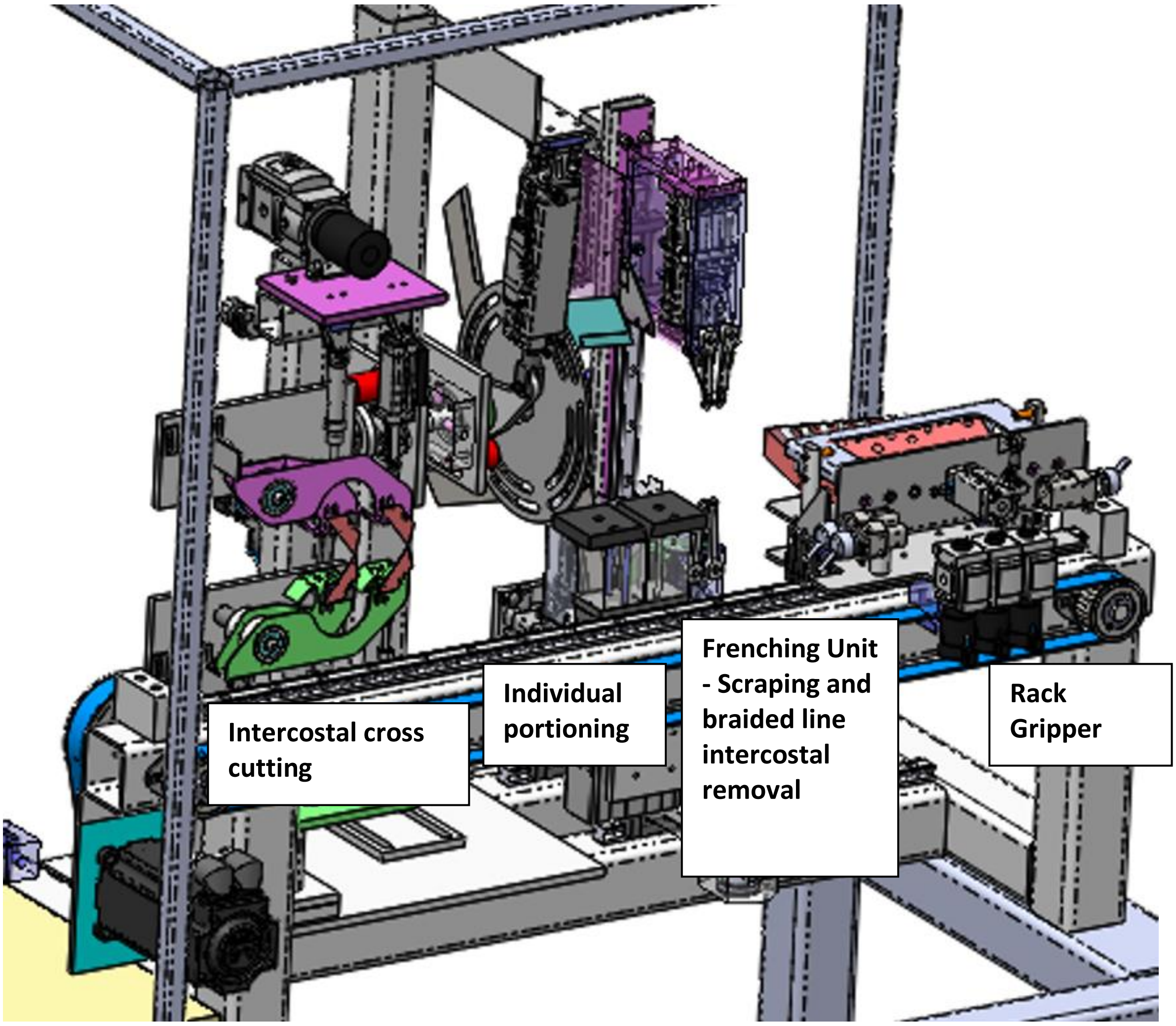


Figure 25: Final design of lamb frenching proof of concept prototype – ready for manufacture

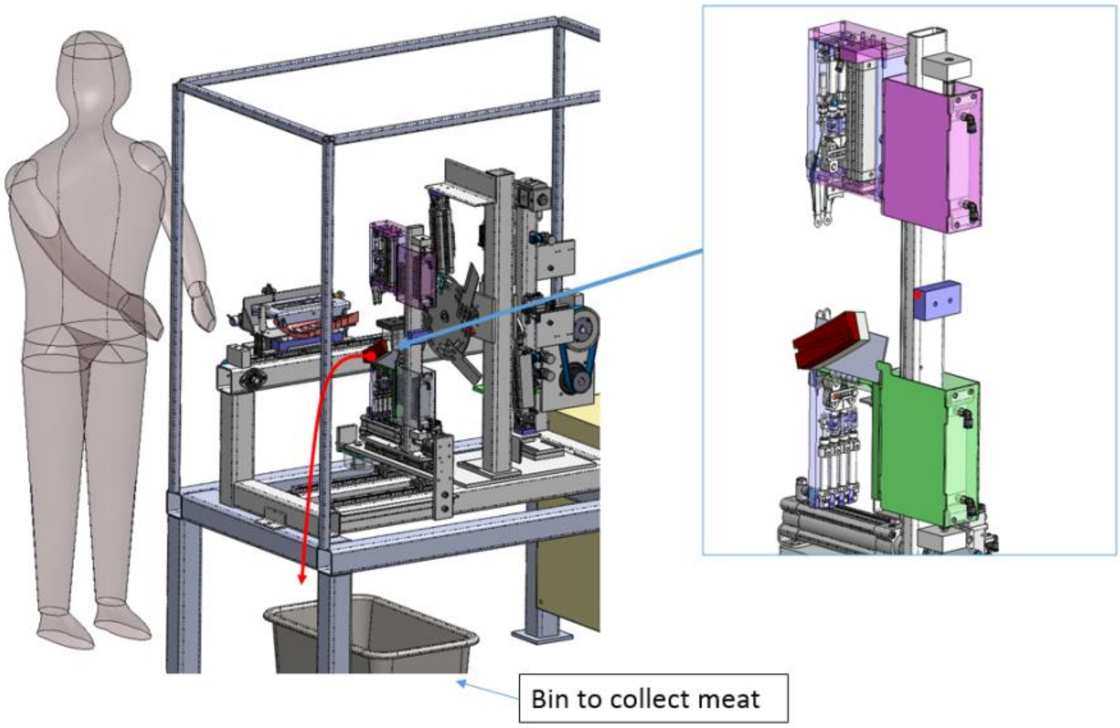


Figure 26:View from behind showing Meat Collection Mechanism

One of the key system requirements is the recovery of removed intercostal meat (yield). The drawing above shows the designed meat collection mechanism, which will deposit the removed intercostal meat into a bin located directly below.

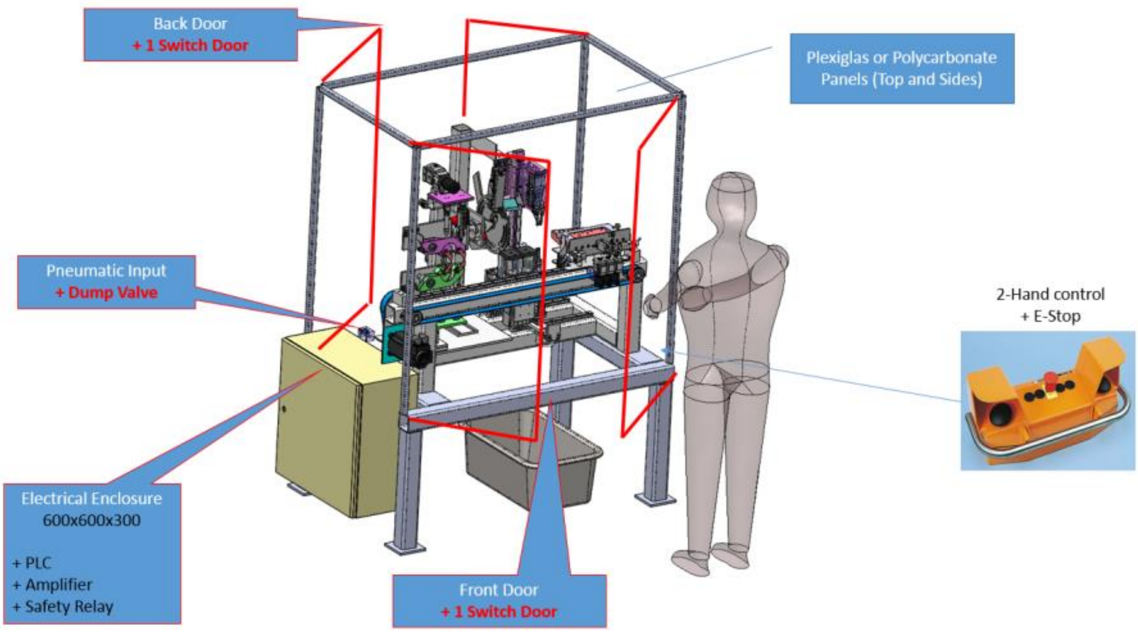


Figure 27:Electrical Design and Guarding

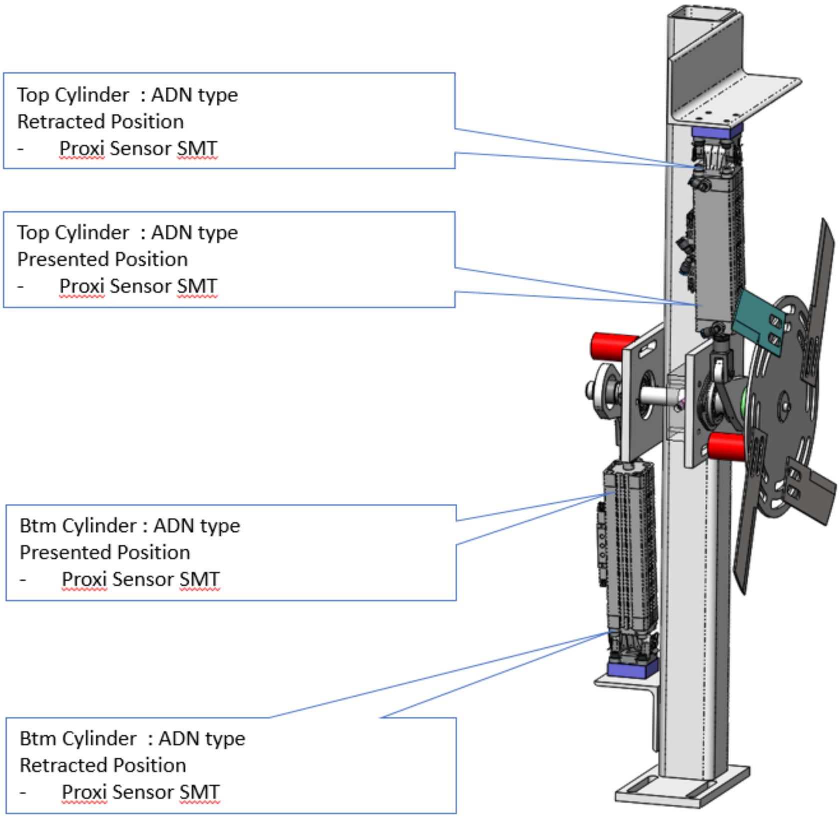


Figure 28:Portioning unit (Splitter) final design – ready for manufacture

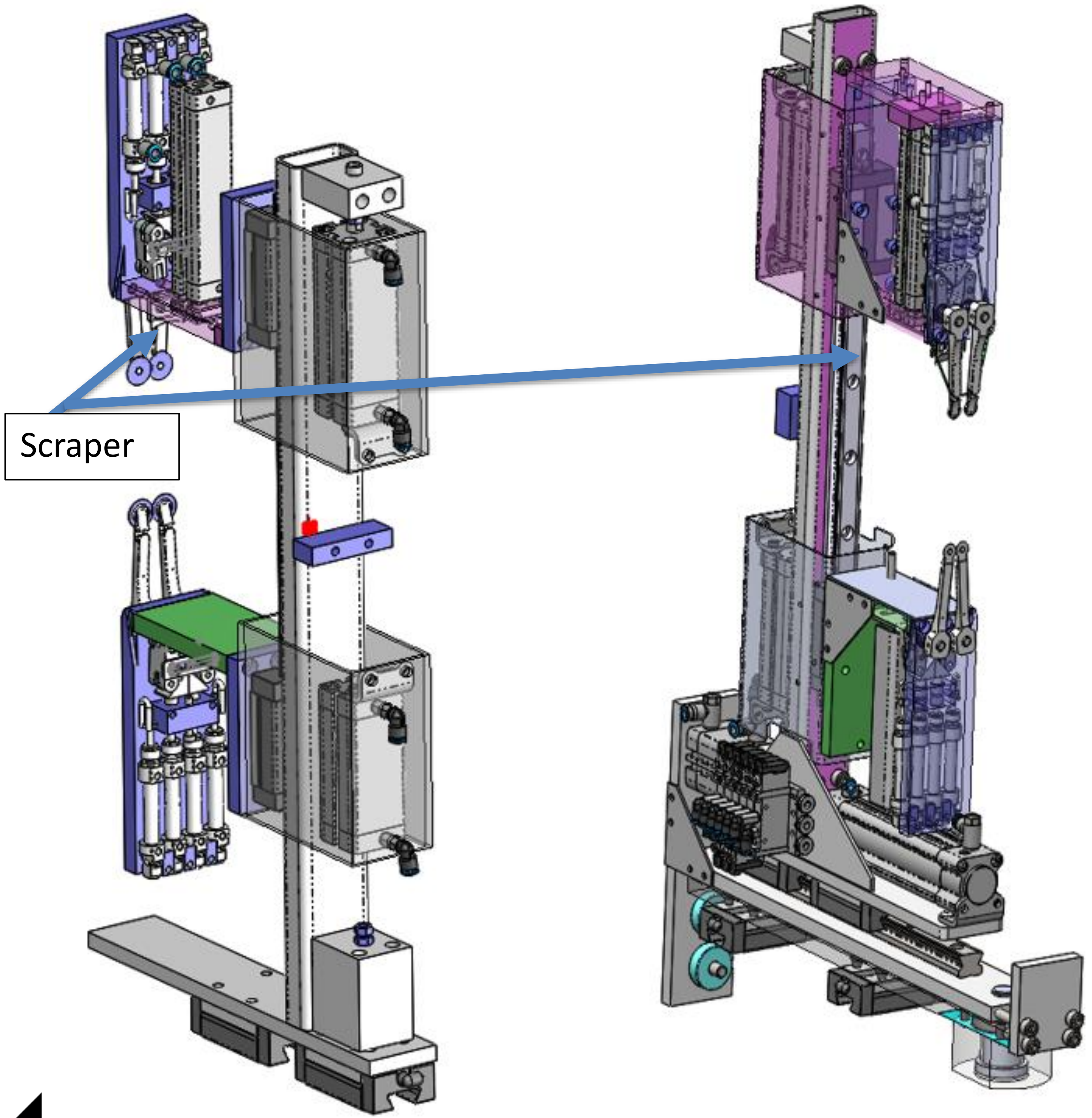


Figure 29:Original concept, view from behind, showing Scraper

Figure 30:Frenching Unit final design – ready for manufacture

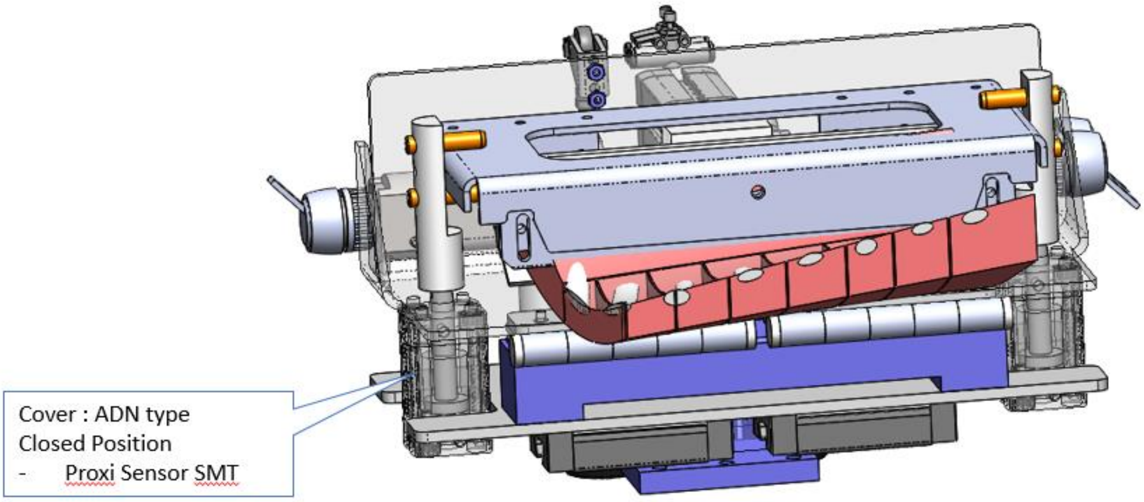


Figure 31: Final design of Gripper Mechanism – ready for manufacture

The gripper was identified by the design team as being crucial to the entire unit operation. The rack must be held in a constant position as it moves through the frenching system.

The system was finally manufactured and prepared for FAT and site production trials.

Figure 32 Final Prototype with covers removed

Figure 33 Prototype at Site (with covers)

7.0 FACTORY ACCEPTANCE TESTING

Following prototype modifications for site-suitability and reassembly, the prototype needed to be extensively retested.

This was carried out by putting product through the machine for a period of 20 working days. The following figures show samples of the frenching result from racks of lamb after modifying the prototype.

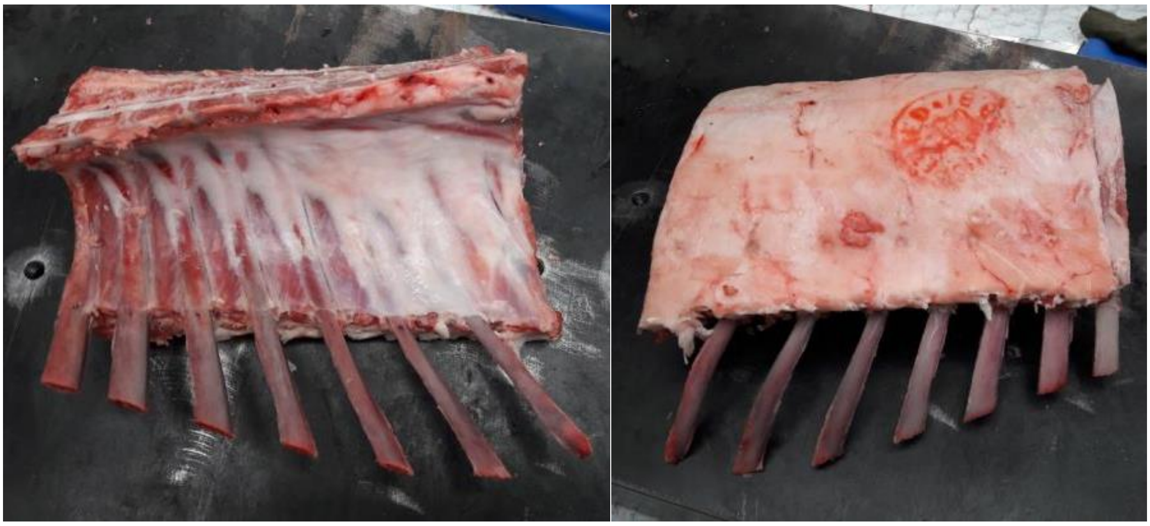


Figure 34: Results achieved after FAT with modified prototype

In addition to photographs having been taken during FAT testing, each of the 101 racks tested were also immediately analysed according to four criteria:

- PROFILING: Performance regarding finding the bones on the rack with the mechanical sensor.
- SPLITTING: Assessment of whether we split the intercostal without hit the bone.
- FRENCHING: How effective the needles moved around the bones to pull the meat off
- CLEANLINESS ASSESSMENT: How clean are the ribs after the full process? The aim is 100% clean.

Table 2: Analysis of racks tested during FAT

				CLEANLINESS ASSESSMENT Rib No								
	Profiling	Splitting	Frenching	1	2	3	4	5	6	7	8	9
All samples	95%	91%	85%	76%	82%	80%	89%	71%	65%	65%	62%	
Without short ribs	97%	93%	88%	82%	88%	86%	96%	77%	70%	68%	54%	
On the last 15 Racks	98%	98%	97%	93%	91%	86%	89%	82%	79%	84%	90%	

8.0 SITE ACCEPTANCE TESTING

Following the prototype modifications required for use at site and reassembly the prototype was to be extensively retested.

The trial processed 62 racks in 2 days. Key learnings were:

Product Tested: The product tested on site was different compared to the products tested in the Scott workshop in Christchurch. On the Timaru plant the test racks were very thin. Intermediate steps were carried out to remove the cap and the meat between the cap and the ribs.

Figure 35: The ‘thin’ ribs used at the Timaru plant

We had to add packing between the rack and the gripper to lift the rack up, otherwise the rack could not be clamped into the gripper with enough force, and the rack sat too low to be profiled properly.

Figure 36: Packing had to be used with the gripper in order to clamp the rack

Temperature: We were processing in our workshop with a temperature colder than we had on site. The temperature of the meat was colder, which means that the meat is more compact and easer to be frenched with our wire system.

When the meat is too warm it also gets sticky. Meat gets stuck on the bone or on the wire and makes it difficult to be pushed away.

Positive outcomes:

- The mechanism for sensing the profile of the ribs works well.
- Reliability - in finding the rib positions and using the data to define Frenching and splitting rack position
- Splitting – Reliable split of the intercostal without damaging the bones.
- Fixed indexed positions are working well.
- Positioning rack relative to the splitter is working well.
- Frenching – Positioning rack relative to the centre of the needles is good.
- Cleanliness – we are getting perfect quality on some products.

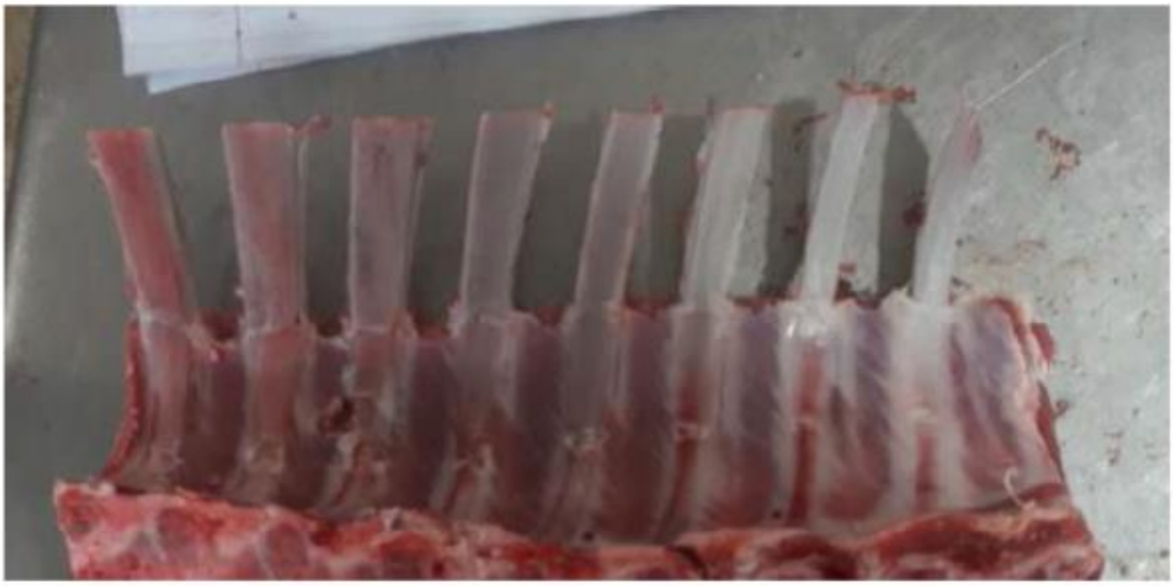


Figure 37: An example of the cleanliness achieved

Areas for further consideration/improvement:

- Meat at the extremity of the bone.

Figure 38: Meat left at the extremity of the bone at the end of the process

- It is observed that the bone was often perfectly clean but that meat was getting stuck at the extremity of the bone. The main causes are –
- Meat temperature – the meat is more sticky than expected.
- Dirty string line – the meat gets stuck around the string line and the string line is not sharp enough to clean the bone for the last part.
- Low quantity of meat removed – the factory process cleans the rack by removing cap and meat. The low quantity of meat is not helpful for us at this stage.
- Meat stuck on the top wire – need to clean the string line one or twice during Frenching.

Figure 39: Meat stuck in the top wire, requiring cleaning

- Breaking string line – On 64 racks we broke the string 4 ties. Always the bottom string.
- String line comes off – sometimes the string line comes off and we have to reposition it into the groove on the needle to continue processing.
- Cannot process short ribs – with the current gripper we cannot process a rack with short ribs.

5.0 CONCLUSIONS/ RECOMMENDATIONS

Trials at site progressed successfully and the results were positive. The team agreed that the trial was sufficient enough for the purpose of this proof of concept for this project. Scott Automation are to prepare a proposal for next phase of project and submit to AMPC. The next project will be a fully commercial system.

A meeting was held after the stakeholder demonstration and feedback from the team was obtained regarding the current and next system requirements:

- Meat to be recovered in the form of intercostal
- System to be designed to handle 10 rack a minute
- Current rib surface finishing is acceptable but there are some room for improvement
- Determine durability of the wire, type and material in wire
- Determine how often the wire needs to be cleaned, introduction of cleansing process for wire to clean up the excess fat, perhaps a bath/hot water tank or a contact/friction/brush cleaning mechanism.
- Wire change procedure
- Longevity of rotary blade and sharpness