final report

Project code: P.PIP.0734

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Date published: 23rd April 2020

PUBLISHED BY
Meat and Livestock Australia Limited
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NORTH SYDNEY NSW 2059

Automated Forequarter Cell Installation for Lamb – Wagstaff Cranbourne Pty Ltd.

This is an MLA Donor Company funded project.

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government and contributions from the Australian Meat Processor Corporation to support the research and development detailed in this publication.

Executive summary

This project served to further develop a standalone (or integrated) forequarter processing cell operating at 5 Carcasses per Minute (CPM). The flexibility of this robot approach is that for food processing operating less than 5 CPM, the cell can also be configured to undertake other value added lamb cutting tasks.

This project took the newly developed single alpha cell and install it in-line at Wagstaff Cranbourne Pty. Ltd.

The installed location enabled Scott, MLA and the site to evaluate and further refine the system in situ. Before this installation this system has only been tested at the Scott factory in New Zealand, this project would allowed for the system to be tested under a production load, operated by multiple different personnel. This gave Scott the ability to find, work on and improve on any aspects of the system.

The project consisted of:

1. A manual load station with scanning and clamping
2. A robot cell with robot, gripper and multi-axis saw
3. Electrical control cabinets x 2
4. Pneumatic cabinet with isolation valve
5. Guarding
6. Software to control the operation of the Ex works hardware

Supply for each element above included all mechanical and electrical hardware to deliver machine function, software to run each machine component, software to integrate between the machine components, electrical cabinets to house ex works control gear, cable droppers, wire termination into Scott supplied electrical cabinets, guarding, manuals, hazard analysis and training.

The Manual Load Forequarter Cell has been successfully installed and commissioned to operate with lamb carcasses. It is important to highlight that the Manual Load Forequarter cell is designed to solely process lamb.

The average overall cut pass rate based on a visual inspection was recorded as +90% for lamb only. Product testing has determined that additional development and testing is required on the robot gripper internal clamps to accommodate product with narrow rib arches.

The project's industry benefits include,

1. Is smaller in footprint (per carcase throughput) at 3687mm x 4920mm.
2. Is able to handle Australian stock.
3. Has reduced cycle time.
4. Has increased yield; and
5. Has reduced final recommended retail price (based on per carcase throughput).

The implication of the work on the red meat industry includes the focus on operator safety, the ability to automate a repetitive and hazardous task and the ease of integration due to having a smaller footprint.

As the system is designed to work with biological variation in product leading to an infinite number of combinations in product composition, this project allowed Scott to further refine the system to be capable of handling the variation found in forequarters presented. One such example is the ability for the system to handle lamb forequarters with narrow rib arches.

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1 Background

This project was undertaken to further develop and have ready for Australian installation, a standalone (or integrated) forequarter processing cell operating at 5 CPM.

The system's significance for industry centres around its flexibility of this robot approach is that for processing operating less than 5 CPM, the cell can also be configured to undertake other value added lamb cutting tasks. Due to the hazardous and repetitive nature of forequarter processing, implementation of this system enables the operator to consistently produce a higher quality yield at a greater rate of throughput while insuring their safety and wellbeing.

Overarching aims of this project include, the continuous improvement of the system around working with the physical biological variation in lamb forequarters

In 2012 Scott concluded the first example prototype of the LEAP V automated bone-in forequarter processing cell. Feedback from processors was that the system was excellent in the way that it handled and processed the product however too many cells were required to support a room operating at 10 CPM. This was both a comment based on the required total investment for a 10 CPM processing environment and the footprint required. This was used to develop the alpha forequarter cell that has only been tested at the Scott Dunedin factory. This project aims to carry forward these learning's into site trials, which is detailed in the following sections.

2 Project objectives

At the completion of this project, a solution was developed for the Australian market that is of a higher quality than the one currently existing. This was carried out by installing this system at Wagstaff Cranbourne Pty. Ltd. so that its performance could be evaluated.

The project's objectives included,

- The installation in situ of the Scott- MLA evolved FQ bone-in single cell alpha prototype at Wagstaff Cranbourne Pty. Ltd.

3 Methodology

3.1 Site Integration Plan

In order for the integration plan to be determined, site (Wagstaff Cranbourne Pty. Ltd.) had to be visited so that a plan could be put into place. Images were taken so that the integration plan could be designed at Scott. Cable runs were planned and access to service such as electricity and compressed air was assessed. It was decided that cables will be run on the celling and services would run into the robot cell through conduit droppers.

Fig. 1 Forequarter Machine Installation Room

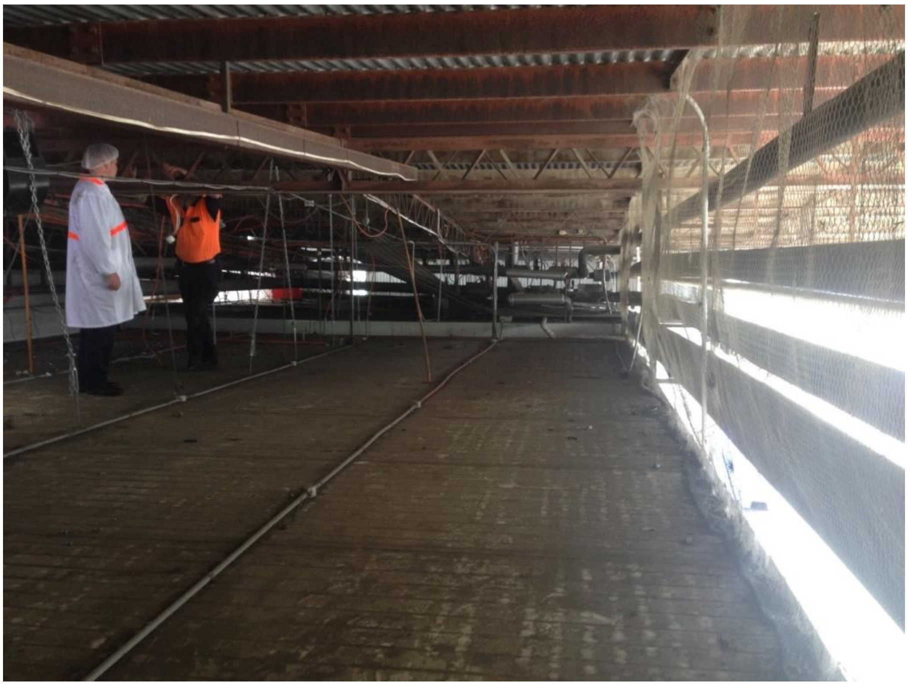

Fig. 2: Ceiling Cavity above Forequarter Machine Installation Room

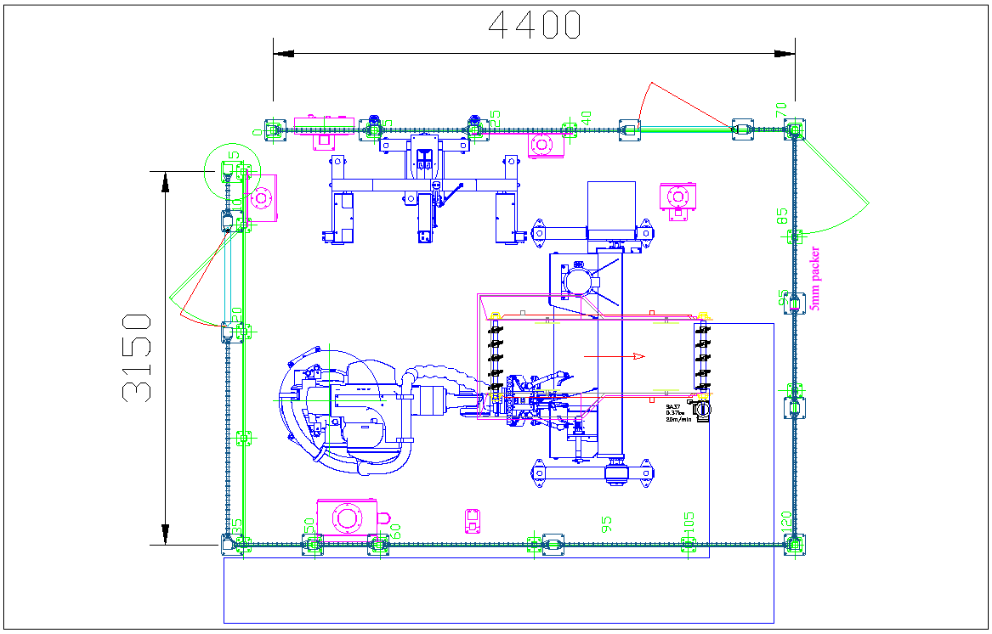

Fig. 3: Robot Cell Drawings

There were some room modifications required that had to be carried out in order to allow this system to be installed. The walls around the nominated room to be taken out, the concrete slab on the ground was not thick enough (with sections of 75-100 mm) and the requirement for the robot to be stable was 200mm. As a result, a 2000 mm by 2000 mm square of concrete was cut out and replaced with the thicker slab. In addition to this, the movement of a column was carried out, such that enough space was allowed for the installation. This was coordinated between Scott and Wagstaff Cranbourne Pty. Ltd.

3.2 Installation

Initially, the Forequarter system and fencing was drilled into the concrete in the room setup for the installation at Wagstaff Cranbourne Pty. Ltd.

The robot controller and panel was installed out of the room, in a separate area, this was due to the fact that the controller cabinet wasn't suitable for application in a clean room/wash down environment.

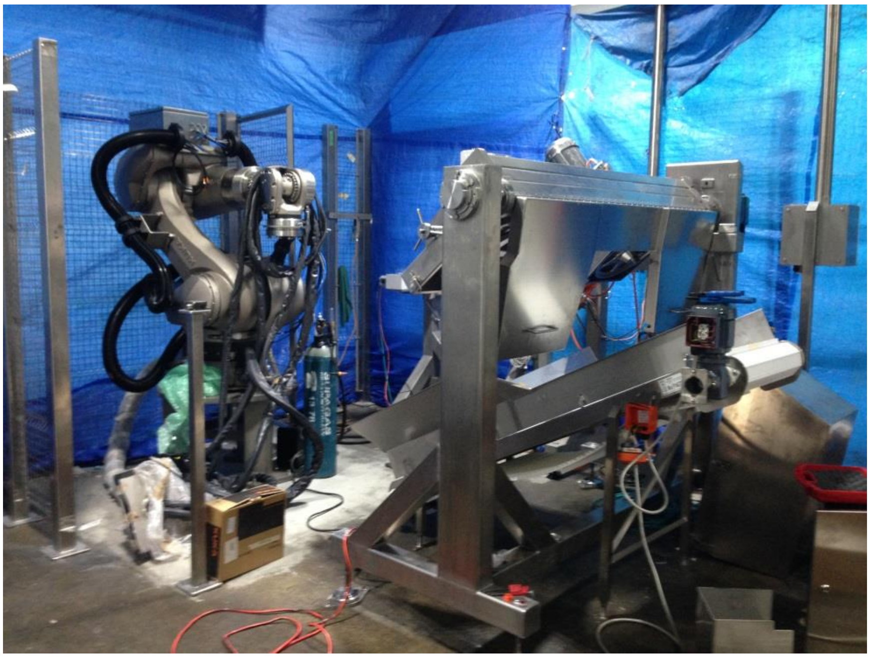

Fig. 4: Robot System Installation at Wagstaff Pty. Ltd.

Following the hardware install the system was commissioned over a number of site visits. The tasks completed during these visits are detailed below:

3.3 Site Visit 1 – 26th June 2017 to 28 July 2017

The initial commissioning and testing phase was conducted during site visit 1. These tasks included:

- Commissioning of automatic and manual controls
- Robot / bandsaw setup and calibration
- Robot / Vision calibration
- Preliminary cut trials

During the preliminary cut trials, a number of process issues were identified with the cell. These issues ultimately resulted in poor cuts – primarily in the ‘split’ cut. These issues include:

- Inability to load product ‘square’ on the load table
- Product movement on the load table during pick up
- Product movement during cutting
- Bandsaw blade deflection during cutting

Fig. 5: Operator HMI and Controls

Fig. 6: Load Table with Light Curtain

Fig. 7: Operator Access Gate

Fig. 8: Robot Controller and MCC

Fig. 9: Stargate Camera Frame

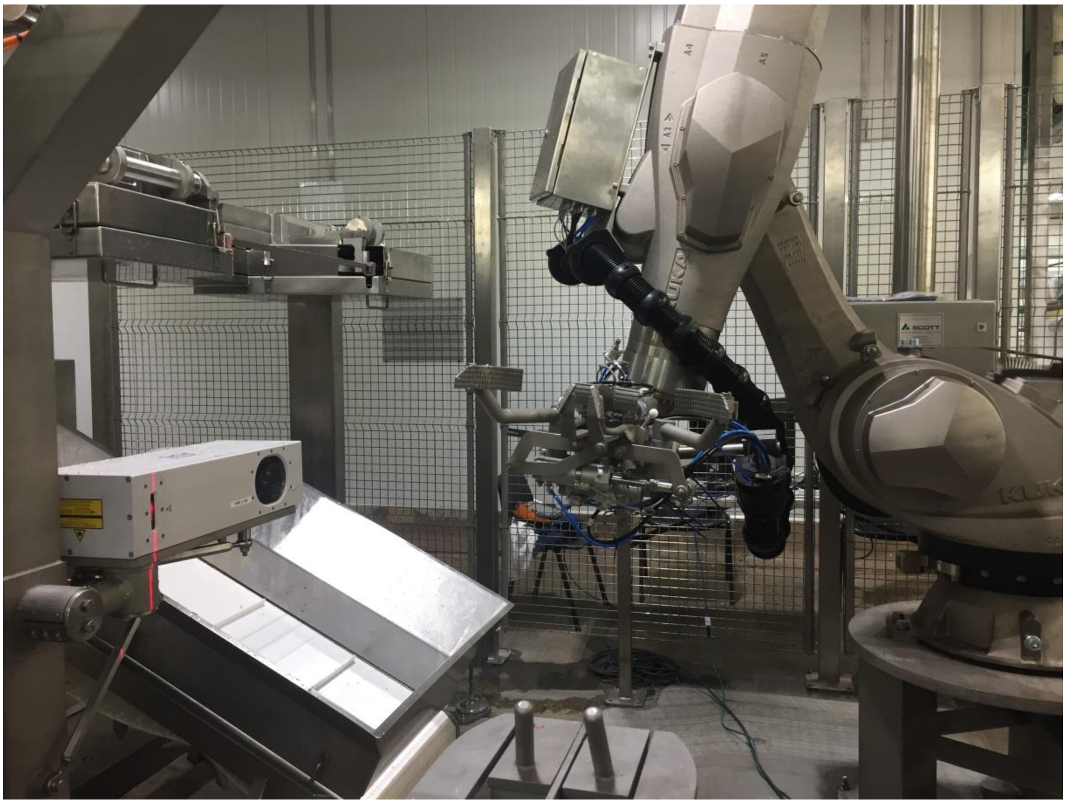

Fig. 10: Robot with Gripper, Bandsaw, and Product Conveyor

Fig. 11: Robot with Gripper, Bandsaw, and Product Conveyor 2

3.4 Site Visit 2 – 6th Sept 2017 to 7th Sept 2017

During Site visit 2, members of management and the design team attended site to observe and assess the issues raised during commissioning and develop a number of options for trial. Limited batches of lamb were run to identify issues, and a number of components were redesigned and manufactured.

Issues identified:

- Product issues
    - Product Primal cut plane not straight (angled and curved)
    - Product temperature outside ideal ranges
- Gripper issues
    - Gripper fouling on product during pick sequence – typically locating pins or internal clamps
    - Product not held securely in clamp during cutting
- Load Table issues
    - Product movement when table lowers
    - Some product did not sit hard up against the locating pins
- Bandsaw issues
    - Blade deflection during cuts
- Vision analysis issues
    - In order to cater for the variability of the product, it was determined that modifications were to be made to the vision analysis software

3.5 Site Visit 3 – 3rd Oct 2017 to 13th Oct 2017

Components were designed and fabricated by Scott New Zealand and shipped to Australia for additional trials. Modifications were tested iteratively, with small quantities of lamb processed after each modification to validate the change. These modifications include:

3.5.1 Load Table modifications

It was found that the locating pins on the load table were too long, resulting in minimal contact between the forequarter rib arches and the locating pins during loading. This typically resulted in product being loaded askew, and ultimately producing bad cuts. The locating pins were replaced with interchangeable pins, allowing pins of different lengths to be tested.

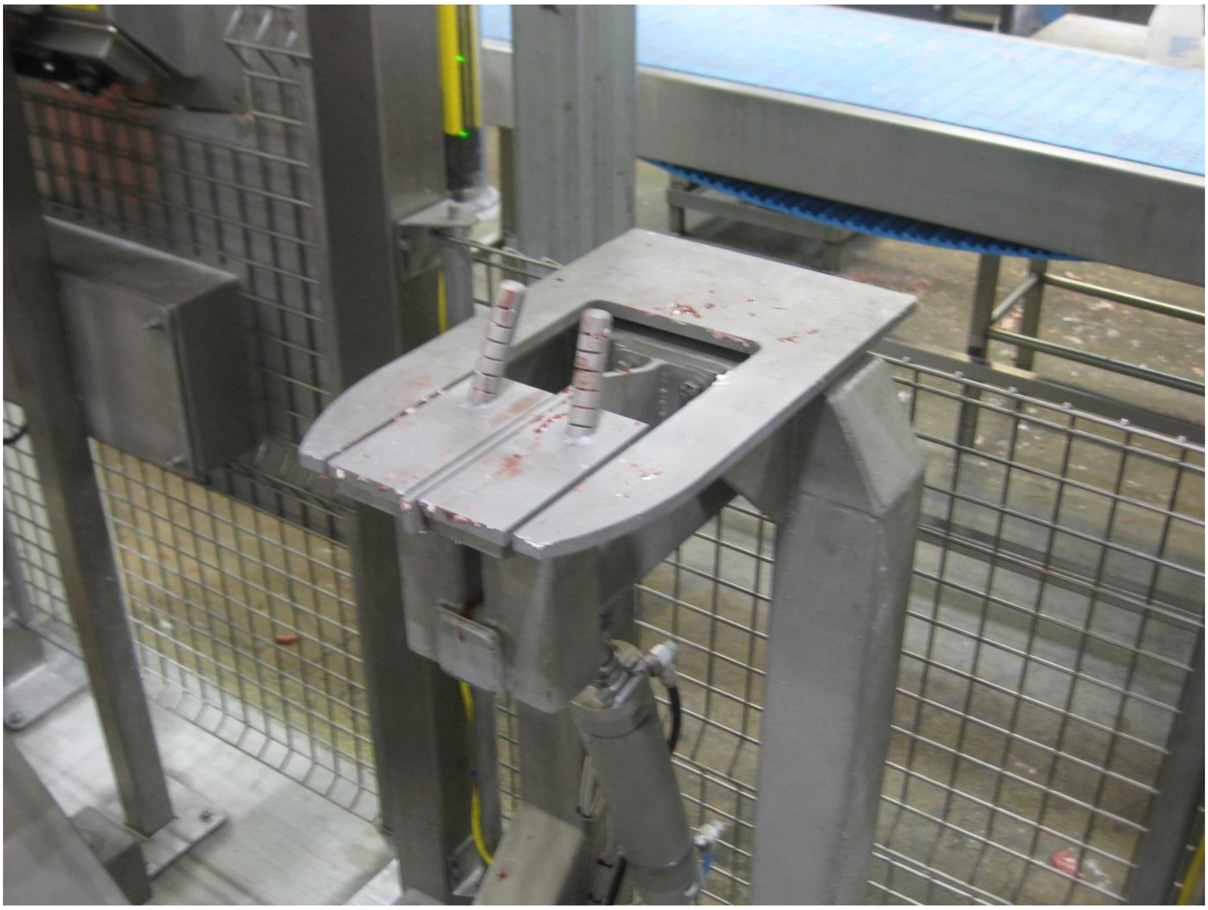

Fig. 12: Original Load Table

Fig. 13: Modified Load Table Locating Pins

3.5.2 Centring pin trials

A centring pin was trialled to positively locate the spinal cord cavity during loading. The pin is fitted on a slotted slide on the load table centre support beam. This ensured product of all sizes can be catered to. Two pin variants were tested:

- Spiked pin; and
- Cylindrical pin.

Both pins worked very well, providing three points of localisation when loading the product. Unfortunately it was very time consuming to load each product as the operator had to visually guide the spinal cavity onto the pin to ensure the product was correctly loaded.

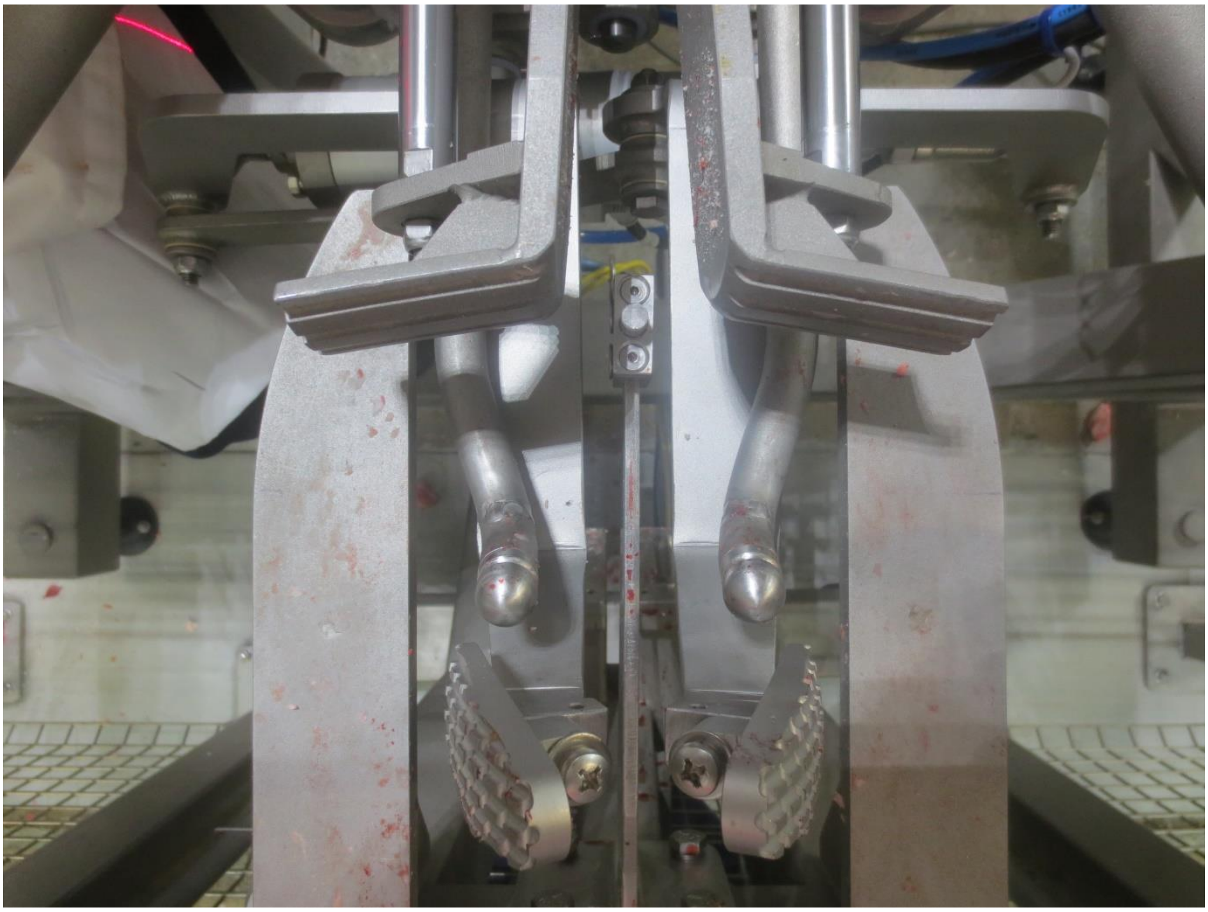

Fig. 14: Load Table with Centring Pin

3.5.3 Gripper Modifications

The locating pins in the robot gripper were modified to match the load table.

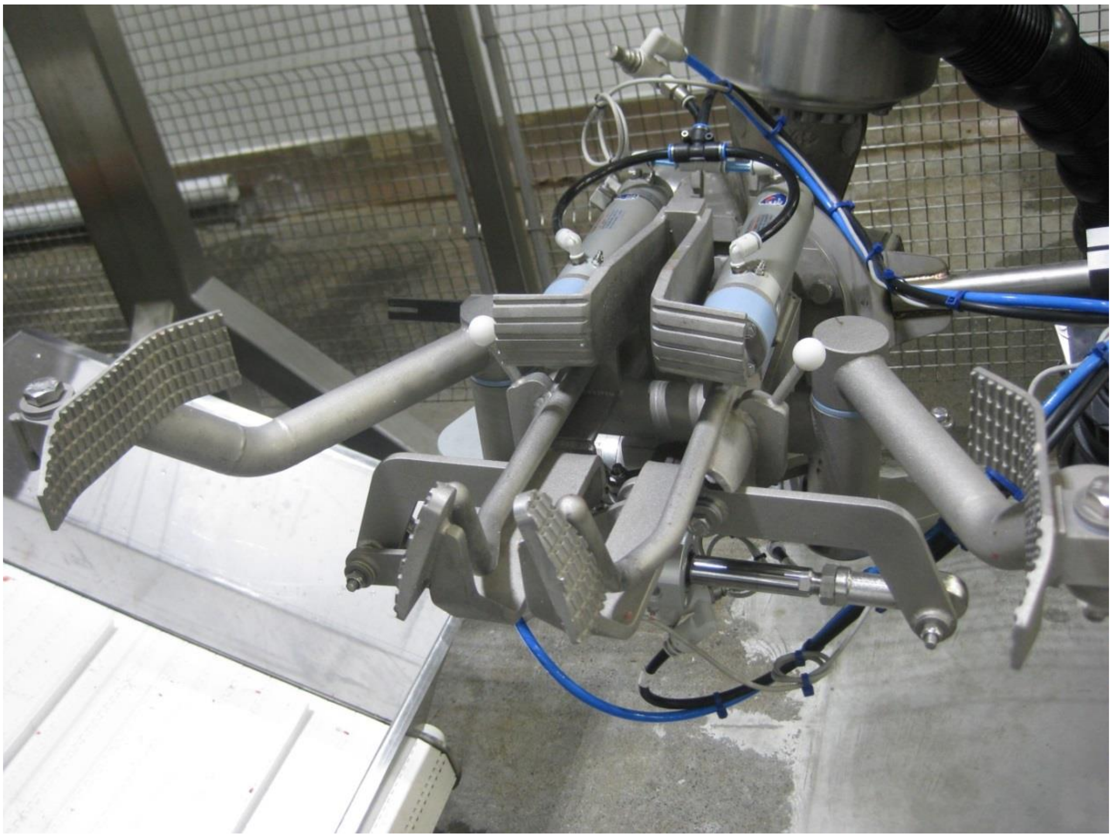

Fig. 15: Original Robot Gripper

Fig. 16: Modified Locating Pins

3.5.4 Bandsaw Cut Position Trials

Video analysis of early cut trials depicted the bandsaw blade deflecting significantly while cutting. This would often result in poor and uneven cuts. Cuts were then shifted closer towards the blade guides where the blade was better supported and therefore less prone to deflection. Ultimately the blade guide on the left side of the bandsaw was shifted 150mm towards the middle of the bandsaw. This reduced the usable area of the blade, but also stiffened the remaining cut area.

3.5.5 Alignment Laser trials

An alignment laser was trialled to assist the operator in positioning the forequarter central to the load table. The premise was to project a crosshair along the fat seam that runs along the centre of the forequarter. The initial trial was deemed promising, however the laser used was too narrow and weak and therefore not fit for the application.

Fig. 17: Initial Laser Trial Setup

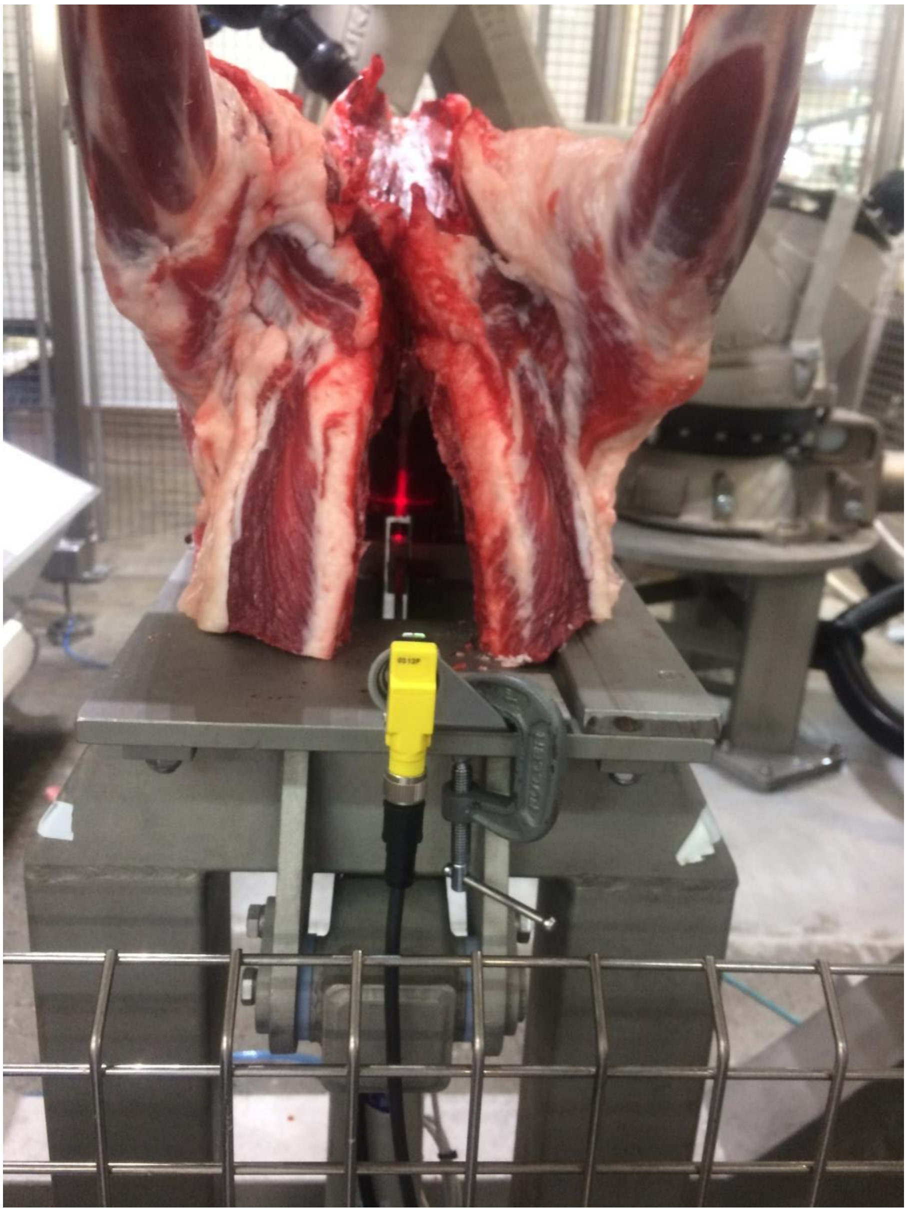

Fig. 18: Initial Laser Trial Projection

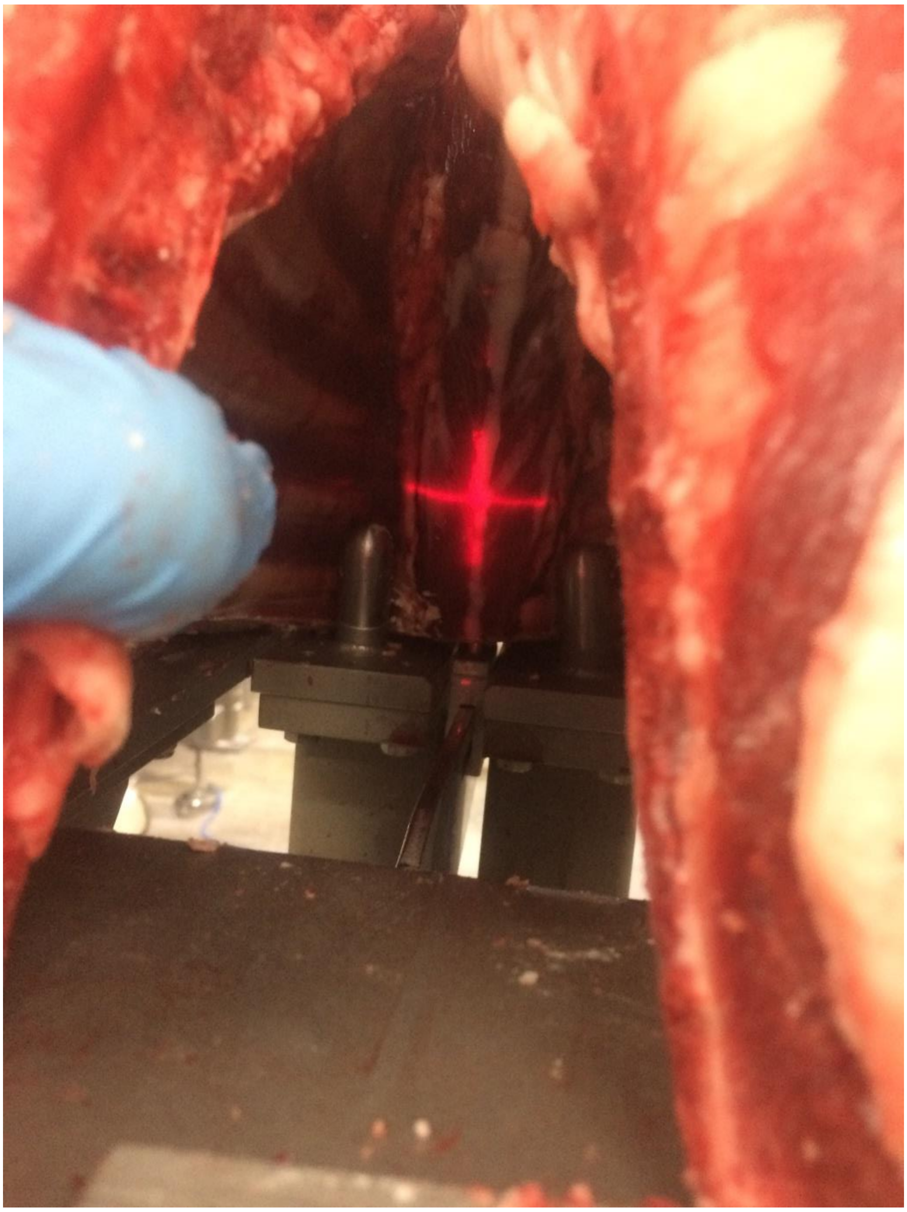

Fig. 19: Initial Laser Trial Projection Close Up

3.6 Site Visit 4 – 13th Nov 2017 to 24th Nov 2017

3.6.1 Bandsaw modifications

New bandsaw blade guide support arms were fabricated to accommodate the new blade guide locations. This was done to ensure the blade guide supporting arms were wholly supported within the blade guide support arm clamps.

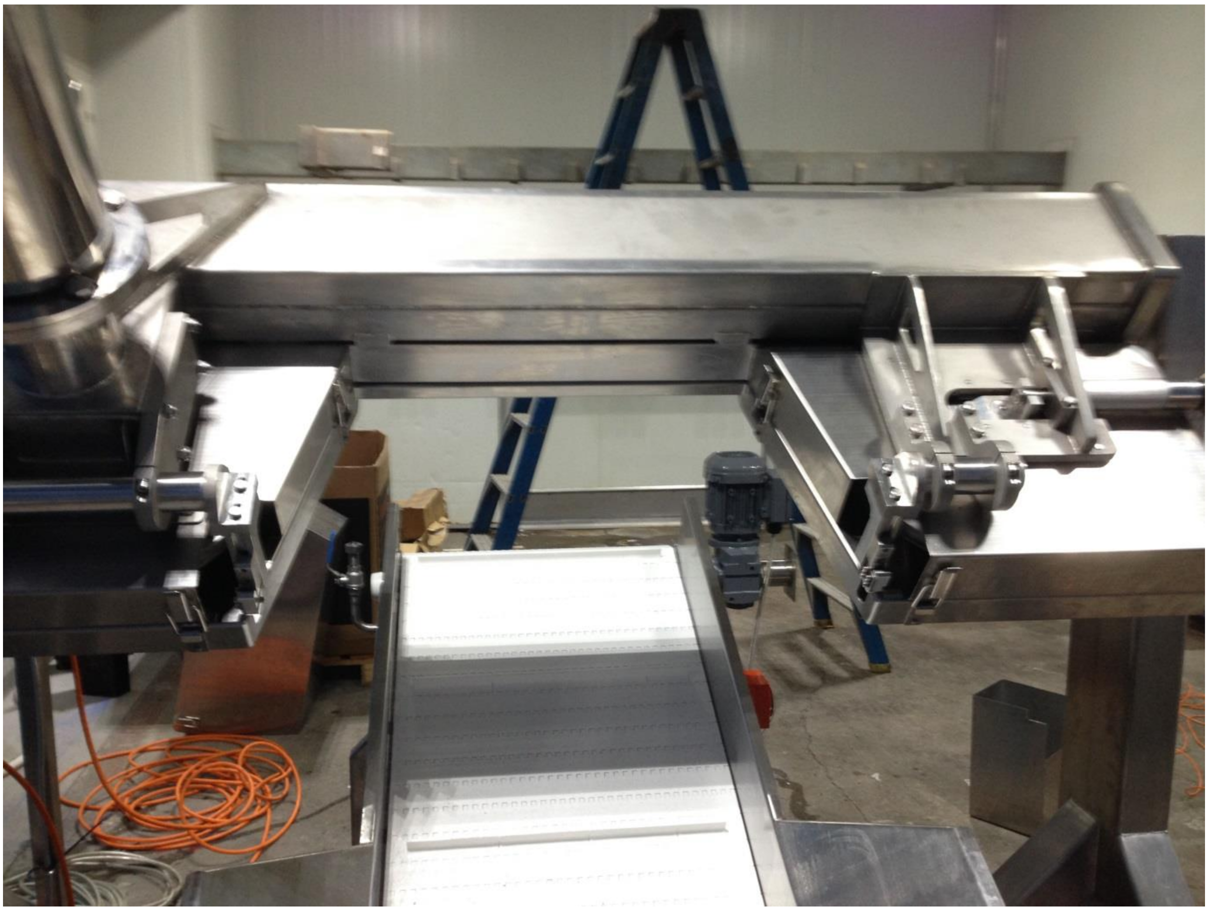

Fig. 20: Original Bandsaw Blade Guides

Fig. 21: Adjusted Left Bandsaw Blade Guide to Fix the Issue of Excessive Blade Deflection and Damage as in the Image Above. The issue has been fixed by modification of guide, bearing, and shaft.

3.6.2 Laser Integration

A high power laser was fitted above the load table to project a line down the centre of the forequarter. This is used to assist the operator in positioning the forequarter central to the load table.

Fig. 22: Alignment Laser

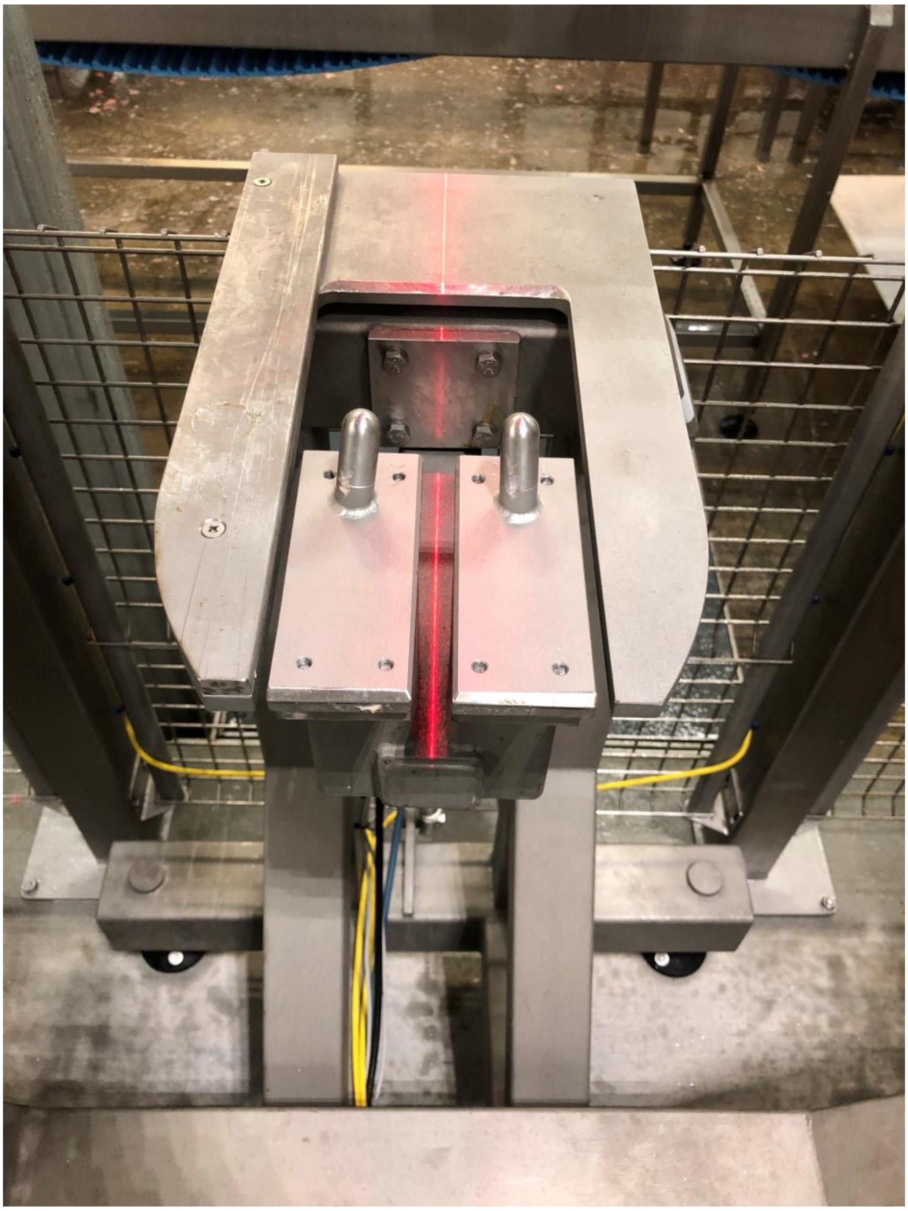

Fig. 23: Load Table with Alignment Laser

Fig. 24: Alignment Laser Projected on Product

3.6.3 Operator Platform

An operator platform was fabricated and commissioned by Wagstaff Cranbourne Pty. Ltd. to raise the operator in line with the load table. This reduced the height that the operator is required to lift the product during loading, and decreased the potential for an RSI related injury.

Fig. 25: Operator Platform – Raised / Lowered

4 Results

4.1 Production Results – Lamb Sampling only

4.1.1 Cut Results Production Day 15/11/2017

- Production run:
  - 189 product through the cell
  - 40 product rejected and not processed
  - 134/149 cut product were acceptable
- Failure breakdown:
  - 5 bad cuts was due to bad shanks
  - 2 bad cuts was due to bad knuckles
  - 1 bad cut was due to bad necks
  - 7 bad cuts was due to bad splits

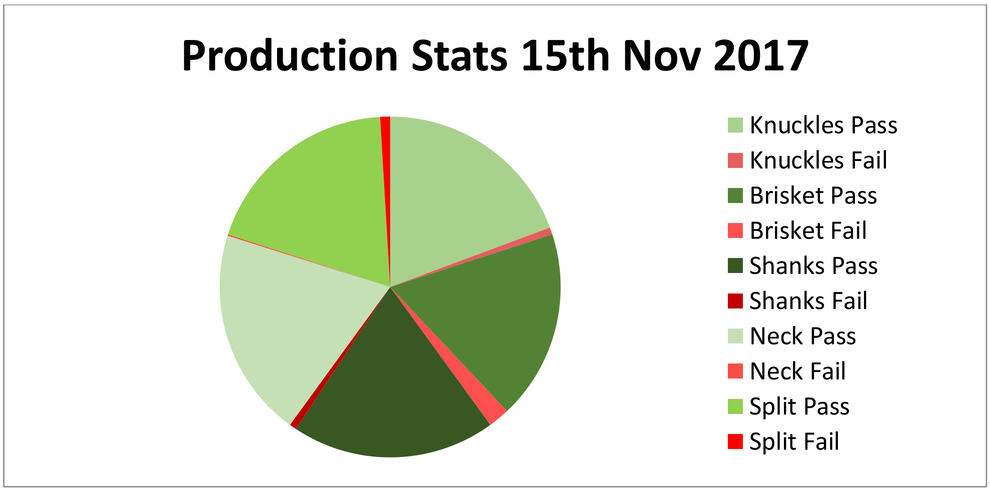

Fig. 26: Production Breakdown 15th Nov 2017

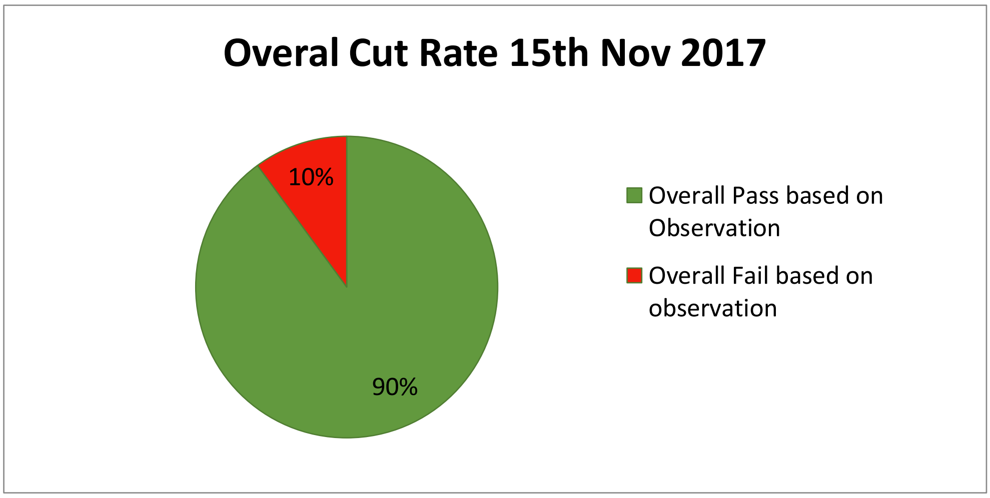

Fig. 27: Overall Cut Rate 15th Nov 2017

4.1.2 Cut Results Production Day 17/11/2017

- Production run:
  - 237 product through the cell
  - 5 product rejected and not processed
  - 194/233 cut product were acceptable
- Failure breakdown:
  - 20 bad cuts was due to bad shanks
  - 4 bad cuts was due to bad knuckles
  - 15 bad cuts was due to bad splits

Note: Bulk of failed cuts was shank / brisket cuts. This was due to batch of large stocky forequarters with narrow rib arches and short legs. Additional development is recommended to design an alternate internal clamp that adequately accommodates all types of forequarter.

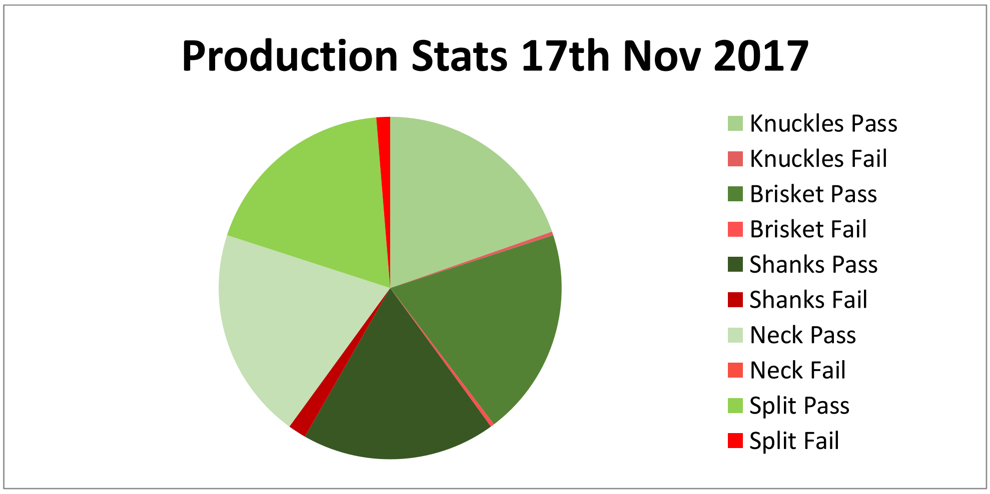

Fig. 28: Production Breakdown 17th Nov 2017

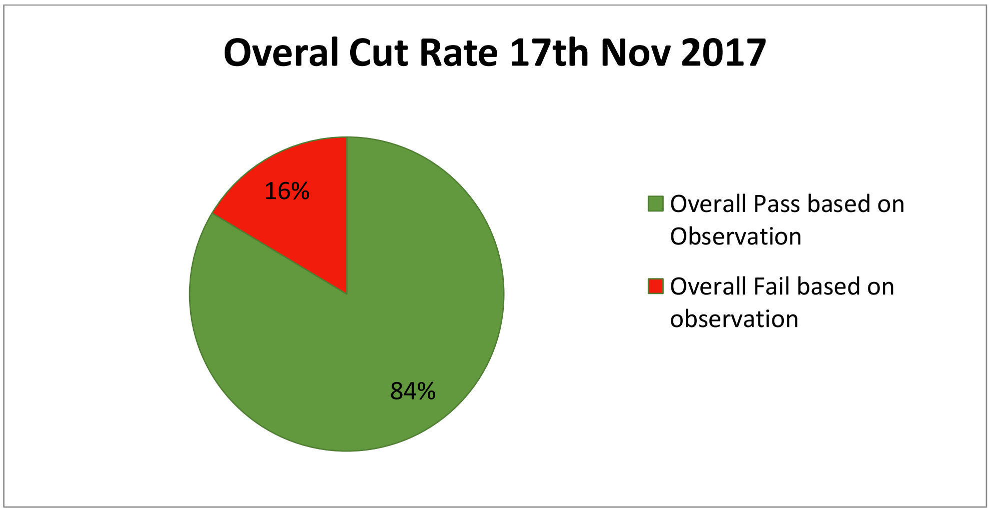

Fig. 29: Overall Cut Rate 17th Nov 2017

4.1.3 Cut Results Production Day 20/11/2017

- Production run:
    - 259 product through the cell
    - 4 product rejected and not processed
    - 230/255 cut product were acceptable
- Failure breakdown:
    - 15 bad cuts was due to bad shanks
    - 5 bad cuts was due to bad knuckles
    - 4 bad cuts was due to bad splits

Note: Bulk of failed cuts was shank / brisket cuts. This was due to batch of large stocky forequarters with narrow rib arches and short legs.

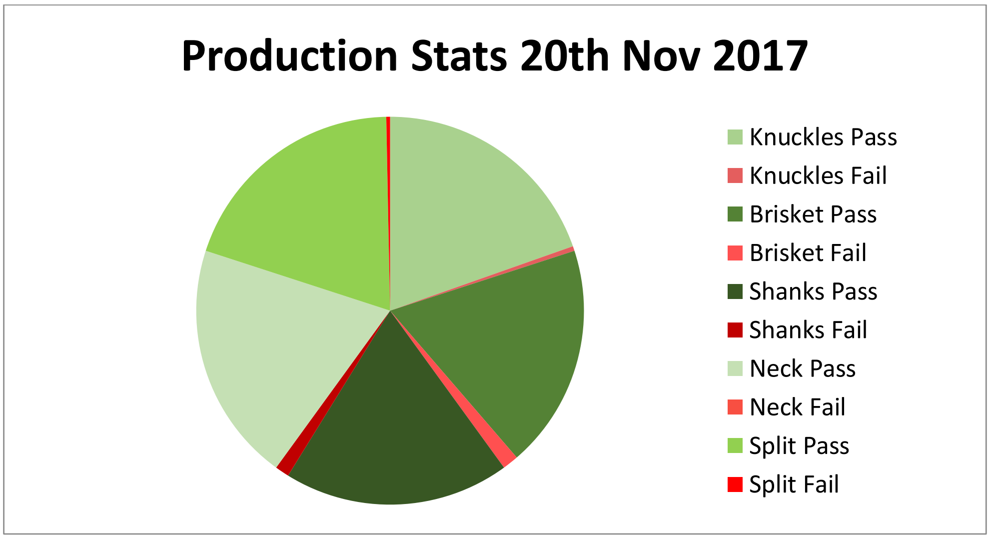

Fig. 30: Production Breakdown 20th Nov 2017

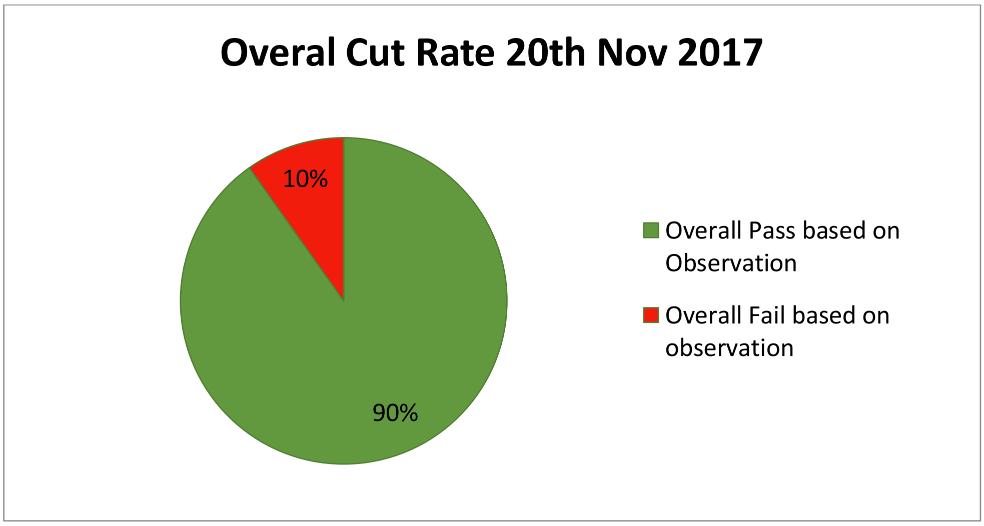

Fig. 31: Overall Cut Rate 20th Nov 2017

4.1.4 Cut Results Production Day 22/11/2017

- Robot feedrate reduced. Bandsaw speed increased.
- Production run:
  - 187 product through the cell
  - 8 product rejected and not processed
  - 168/179 cut product were acceptable
- Failure breakdown:
  - 2 bad cuts was due to bad shanks
  - 4 bad cuts was due to bad knuckles
  - 5 bad cuts was due to bad splits

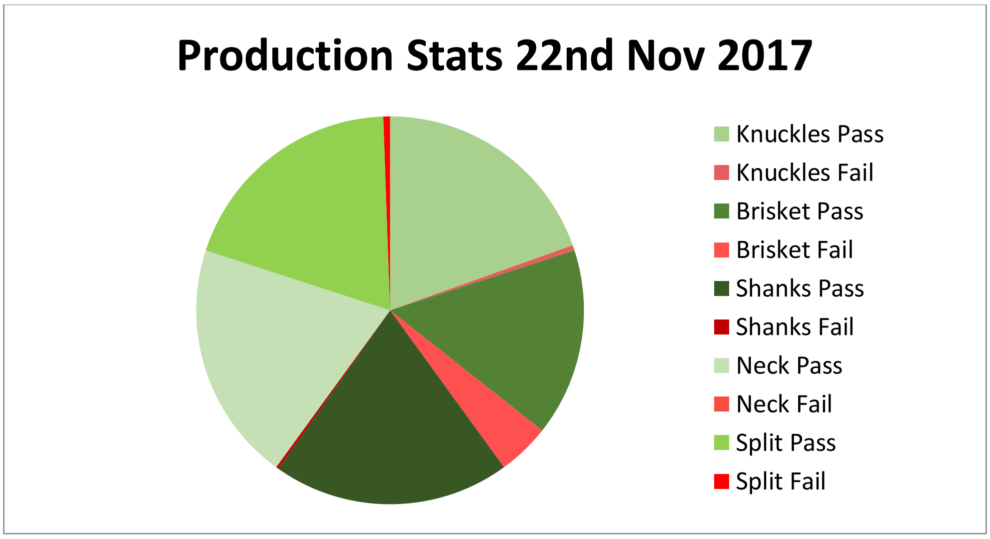

Fig. 32: Production Breakdown 22nd Nov 2017

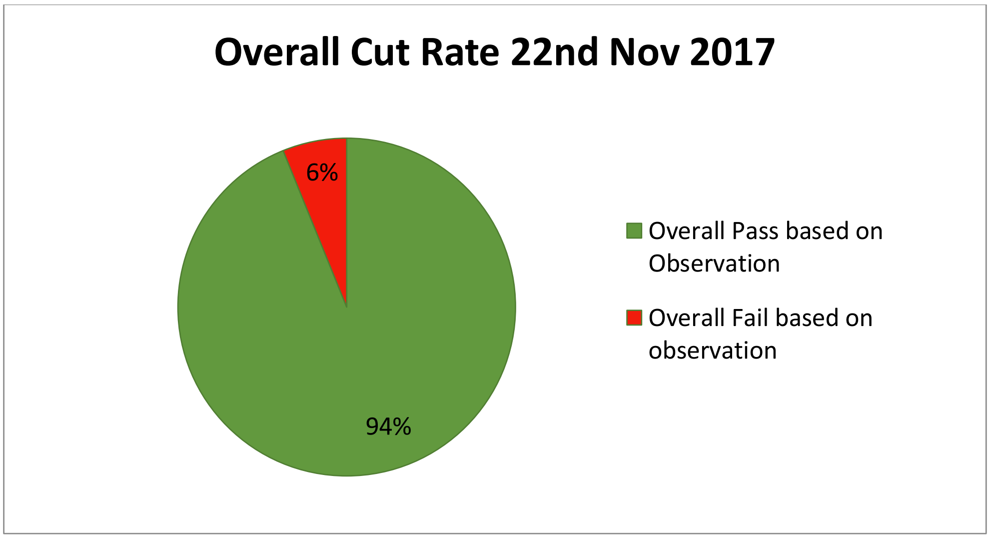

Fig. 33: Overall Cut Rate 22nd Nov 2017

4.1.5 Cut Results Production Day 23/11/2017

- Robot feedrate increased. Bandsaw speed increased.
- Production run:
  - 374 product through the cell
  - 3 product rejected and not processed
  - 346/371 cut product were acceptable
- Failure breakdown:
  - 5 bad cuts was due to bad shanks
  - 11 bad cuts was due to bad knuckles
  - 9 bad cuts was due to bad splits

Note: increase in bad splits was likely due to the tuning of the robot feedrate. Robot feedrate was reduced during break.

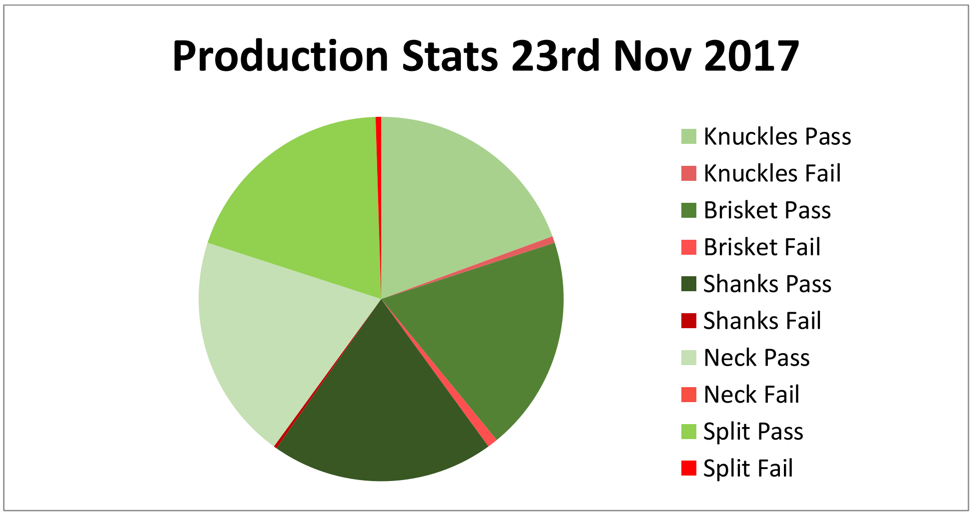

Fig. 34: Production Breakdown 23rd Nov 2017

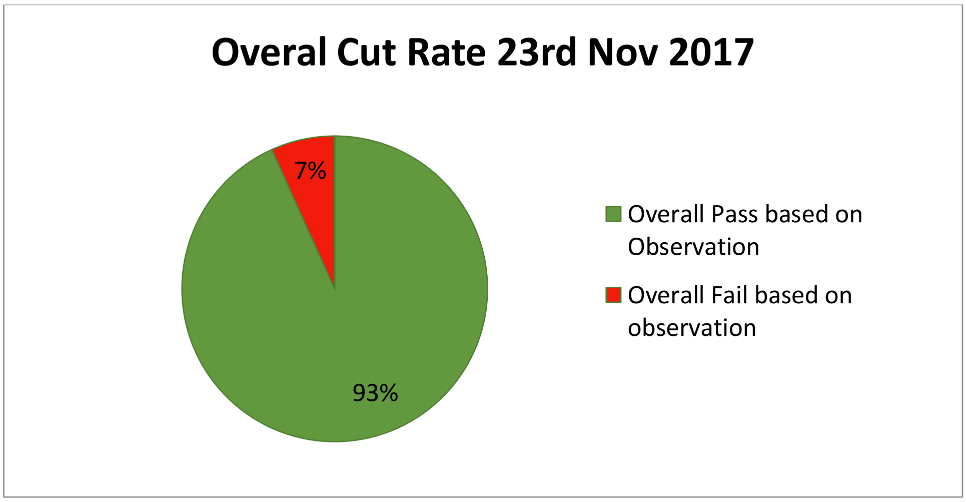

Fig. 35: Overall Cut Rate 23rd Nov 2017

Fig. 36: Product Processed by the Robot 1

Fig. 37: Product Processed by the Robot 2

4.2 Load Table Modification

A new load table with adjustable lifter was designed and fabricated in New Zealand, and commissioned at Wagstaff Cranbourne Pty. Ltd. on 18th January 2018. This modification allowed the table to accommodate product that has been cut askew, and eliminated the need for operators to prop the product up using shims.

All operators and supervisory staff have been trained in the correct operation of the new load table. A small product run was processed with the new table with favourable results.

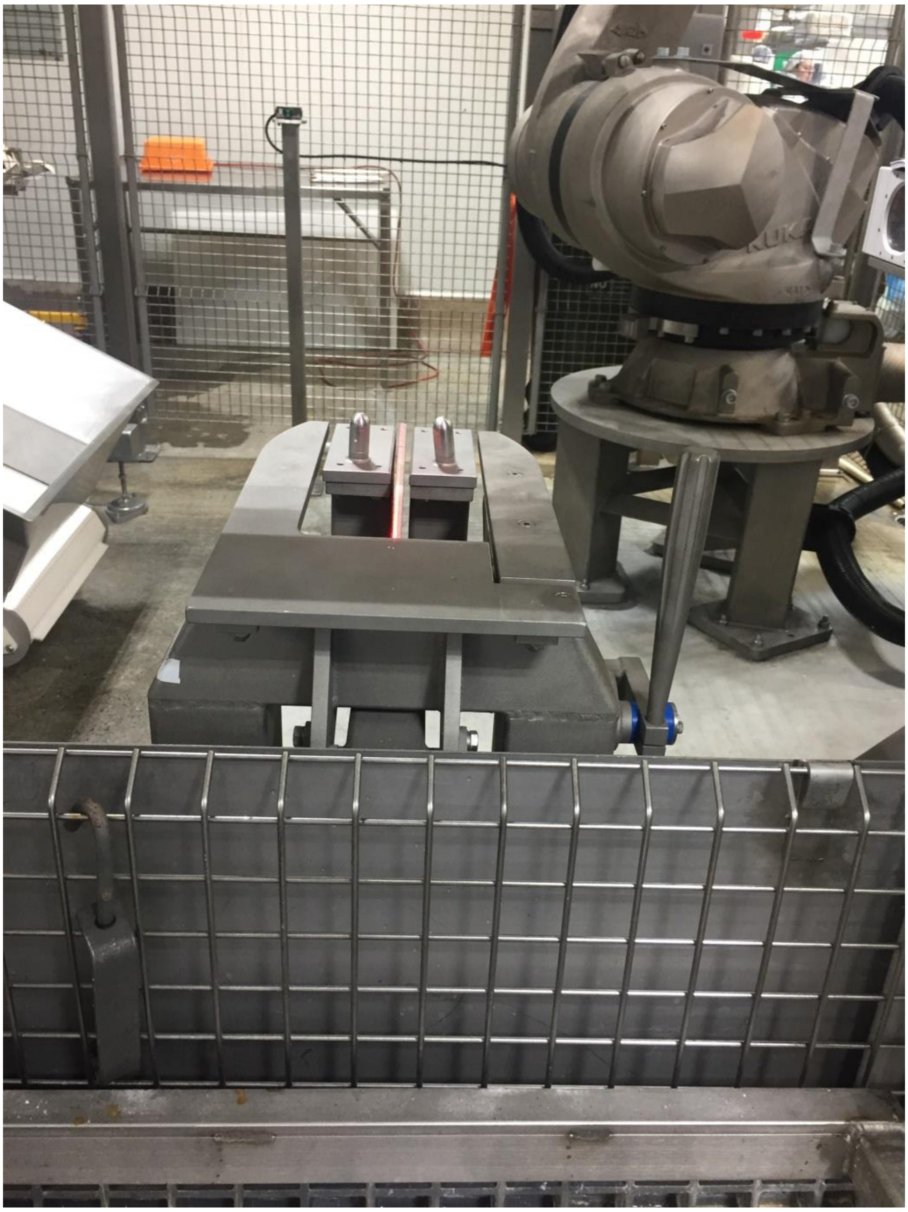

Fig. 38: Adjustable Load Table – Front View

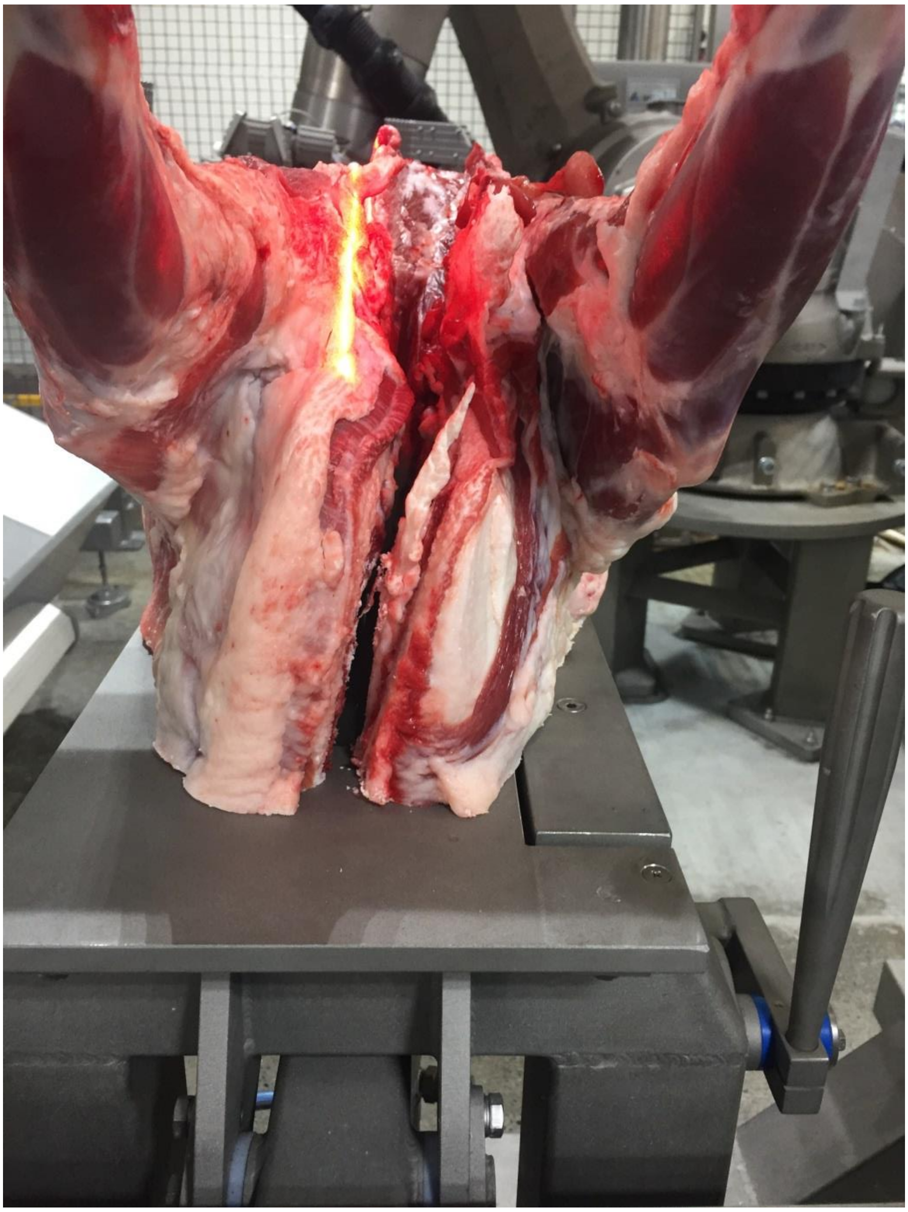

Fig. 39: Product on Load Table Prior to Alignment

Fig. 40: Product on Load Table following Alignment

Fig. 41: Product Processed with New Load Table

5 Discussion

5.1 Issues Encountered

The following section details some of the issues that were to be overcome throughout the commissioning phase of the project.

5.1.1 Product Input

Angled Product

Often forequarters are cut with an angled primal plan. This issue occurs when the carcass is sitting unevenly on the bandsaw while being cut and results in the askew product (i.e. three ribs on one side and four ribs on the other). As the robot and vision system is unable to correct for this offset, it often results in poor split cuts.

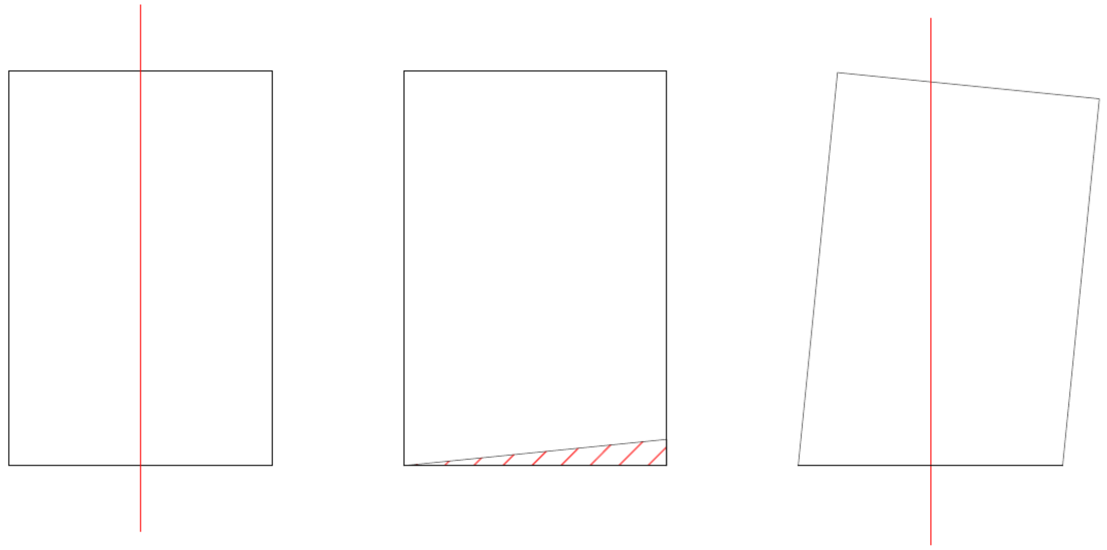

Fig. 42: Ideal Primal Cut (Symmetrical Features) Vs Angled Primal Cut (Asymmetric Features)

Fig. 43: Cut Results on an Angled Forequarter

Fig. 44 below depicts the cut on asymmetric (left) vs symmetric (right) forequarters. The left image clearly shows the split cut path diverges to the side of the product, leaving significantly more meat on the right side of the product and is clearly offset from the spine.

The right image shows a symmetrical forequarter. The cut path follows the spinal cavity perfectly with the blade entering and exiting the forequarter in the centre of the spine. The spinal fluid can be removed as required.

Fig. 44: Split Cut on Angled Product Vs Good Product

The installation and commissioning of the adjustable load table currently caters for the skewed cuts, however it is ideal from the control system standpoint that the primal cut plane be straight. The adjustable load table allows the operator can readily lower / raise one side of the forequarter to compensate for bad primal cuts.

Arced Primal Cuts

Many forequarters are cut with an arced primal cut. This occurs when the saw men push the carcass through the sawblade with one hand, while supporting the carcass with the other. This issue is more common on larger carcasses as they are heavier and more difficult to push through the sawblade.

This can cause issues with the vision analysis results. The vision system calculates the primal cut plane angle and then sets the neck and brisket cut angles perpendicular to it. As the primal cut plane is really an arc, the neck and brisket cuts are sometimes incorrectly calculated and the resultant cuts are acute.

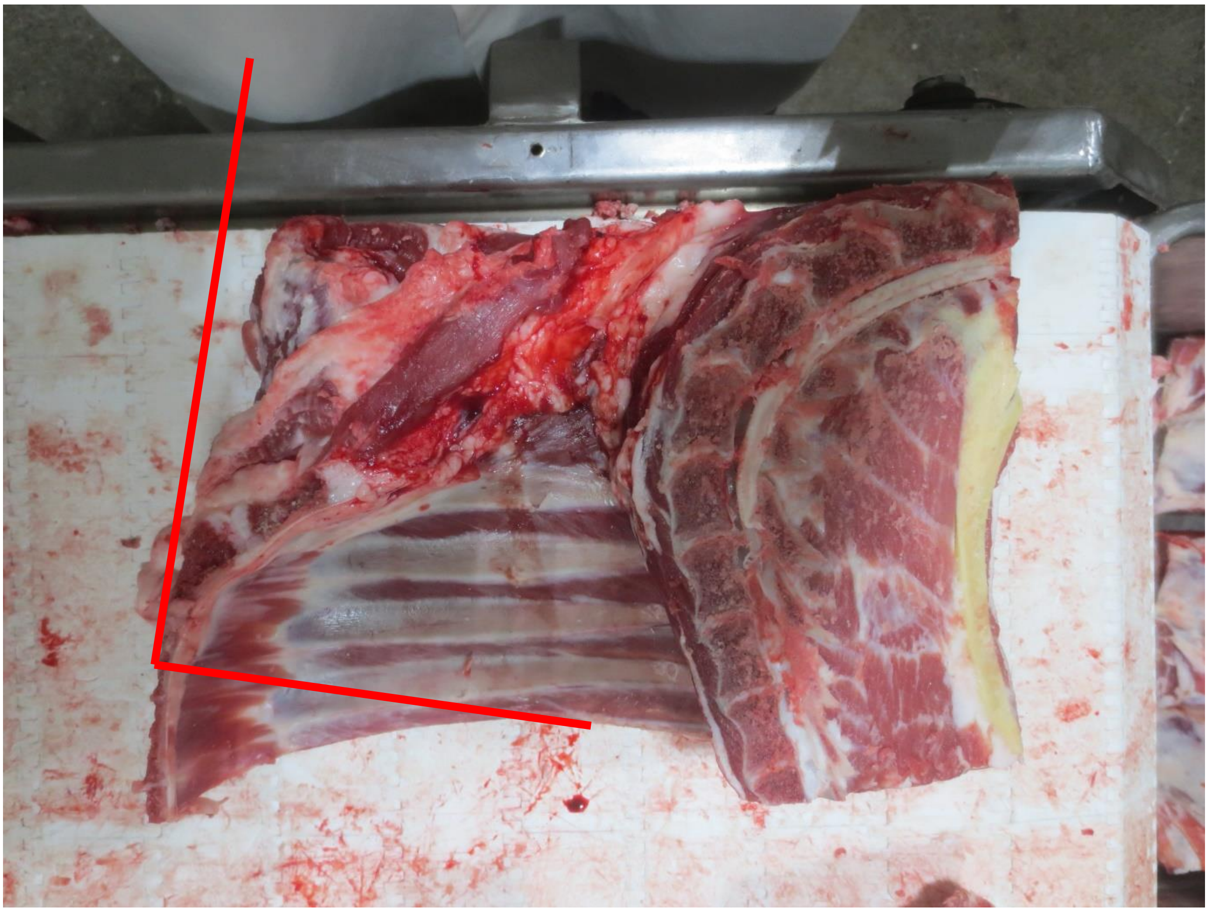

Fig. 45: Arced Primal Cut with Acute Neck and Brisket Cuts

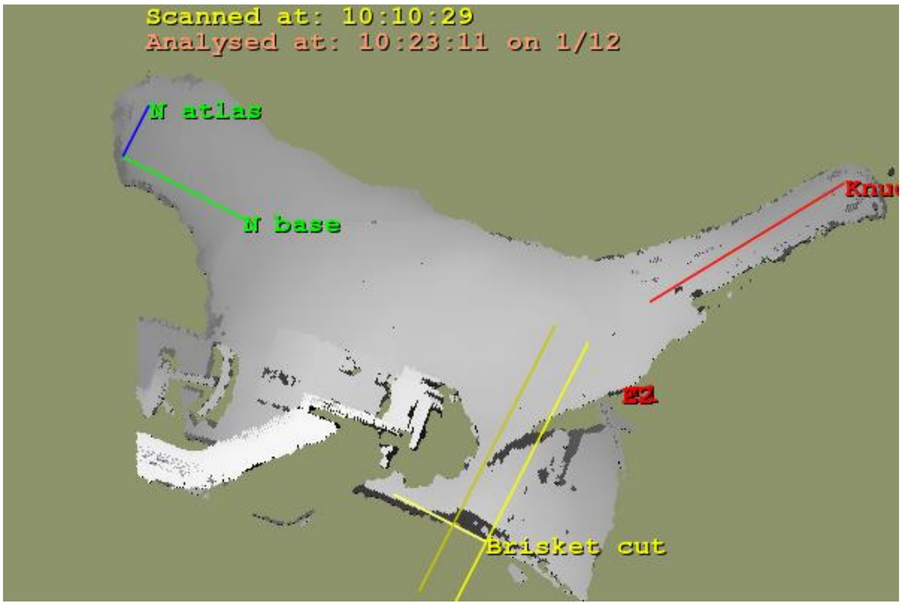

Fig. 46: Vision Scan of Forequarter with Arced Primal Cut (Bad Image Result)

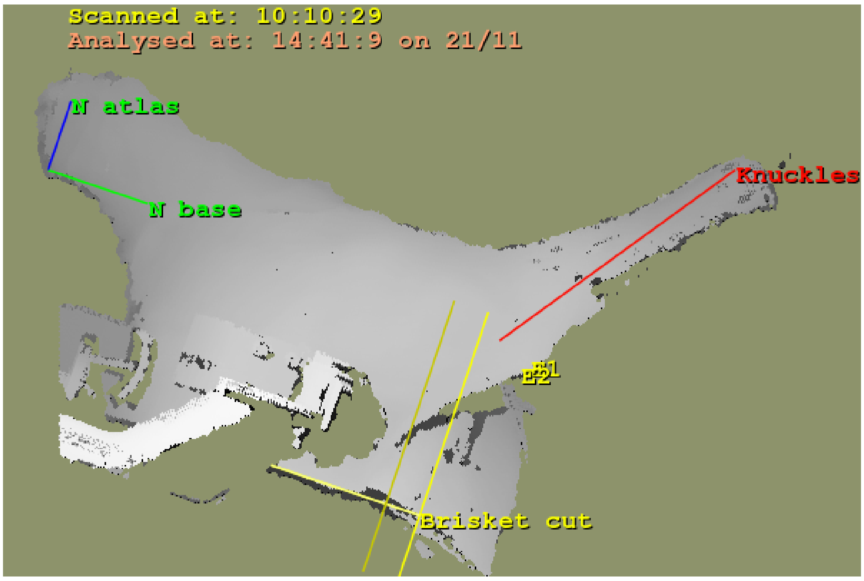

Fig. 47: Vision Scan of Forequarter with Arced Primal Cut (Good Image Result)

Muscle Separation

The forequarters processed at Wagstaff Cranbourne Pty. Ltd. experiences varying levels of muscle separation. This issue is often seen in older animals where the muscles are no longer firm. It is also observed in smaller animals that are excessively stretched during the de-hiding process.

Fig. 48: Muscle Separation Example

Product Temperature

Throughout the commissioning phase, the temperature of forequarters was observed between 6 to 9 degrees Celsius. The system was developed using product ranging from 3 to 7 degrees Celsius. Warmer product is often less firm than colder product, allowing the product to move in the robot gripper and resulting in poor cuts.

5.1.2 Product Return

At present the product return conveyors are still in development. All product processed by the system had to be indexed out of the cell via the placeholder outfeed conveyor, visually assessed, and then loaded into tubs and manually fed back into the boning room. This was a laborious and time consuming task that severely limited the amount of product that could be processed by the system.

Wagstaff Cranbourne Pty. Ltd. is currently undertaking the design, manufacture, and installation of the conveyor network to feed processed forequarters back into the boning room. It is anticipated that these tasks will be complete by mid-January 2018.

Fig. 49: Product to be Fed back into Boning Room

Fig. 50: Placeholder Outfeed Conveyor

5.1.3 Light Noise and Related Issues

The vision system is susceptible to interference from external light sources – particularly natural and fluorescent lighting. These external light sources produce noisy images where features cannot be correctly identified.

In order to minimize noise, stainless steel light guards were hung on the cell guarding. These guards blocked out the bulk of the fluorescent lights from the boning room and drastically improved the quality of the vision analysis results.

Fig. 51: Stainless Steel Light Guards

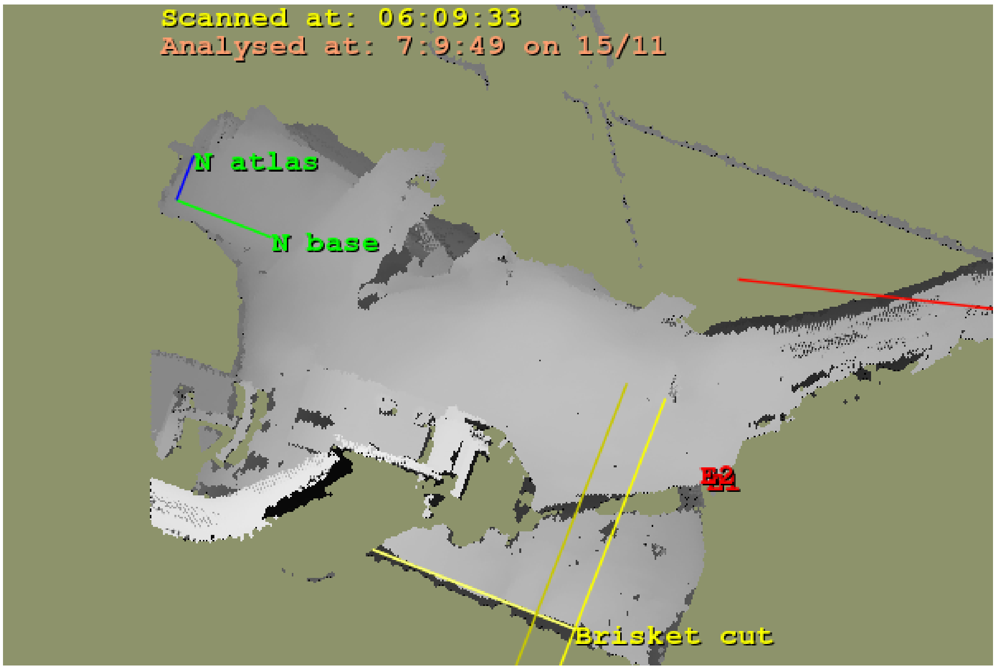

Fig. 52: Vision Scan with Light Interference

Fig. 53: Vision Scan without Light Interference

5.1.4 System Fine Tuning and Support

Further development and support of the Forequarter system since its initial commissioning, this work can be summarised into:

1. Fine tuning the presentation of the product to ensure consistency, regardless of the variation in the product's dimensions. This was required as the gripper was sometimes observed to foul on the product, faulting the system.
2. Calibrating the robot, vision system and bandsaw to minimise feedback error and improve the system's accuracy. This was a necessary to ensure higher yield of the end product.
3. Excessive condensation within enclosures and around the vision sensors was corrected. Condensation could damage sensitive electrical equipment. This was corrected through the addition of silica gel packets.
4. The noise generated by the bandsaw system during operation was also reduced, the noise was indicative of a mechanical fault; this was corrected by changing the bearings and correcting shaft misalignment issues.
5. A new developed agent was applied to the robot arm's surface to rectify some surface discolouration noticed; this new agent is food safe.
6. The bandsaw blades of 3 to 4 "Teeth per inch" (TPI) were tested to investigate any potential improvements in the cycle time, speed of the cut and also the quality and consistency of each cut. The 4 TPI blades did have a small improvement on the cut quality but this was at the expense of a little more pasting on each cut. 3 TPI blades were then selected as they were all round performing better.

Overall, the system's consistency and the quality of the end product were improved upon, steps were taken to minimise downtime caused by environmental factors such as excessive condensation.

6 Conclusions/recommendations

The Manual Load Forequarter Cell has been successfully installed and commissioned to operate with lamb. It is important to highlight that the Manual Load Forequarter cell is designed to solely process lamb. Further research and development is required to accommodate sheep and mutton.

Two operators have been trained and are capable of running the cell unassisted. Wagstaff Cranbourne Pty. Ltd. are in the process of designing and commissioning the outfeed conveyor network that automatically feeds cut product from the robot cell back into the boning room.

In the interim, Wagstaff Cranbourne Pty. Ltd. is committed to limited production runs with the cell to continually provide feedback to Scott Automation. Once the outfeed conveyor network is complete, the Manual Load Forequarter cell will be put into full production.

6.1 Future Works

Additional investigation and research activities will be required under a future project to accommodate larger species such as ovine and mutton including products with narrow rib arches.

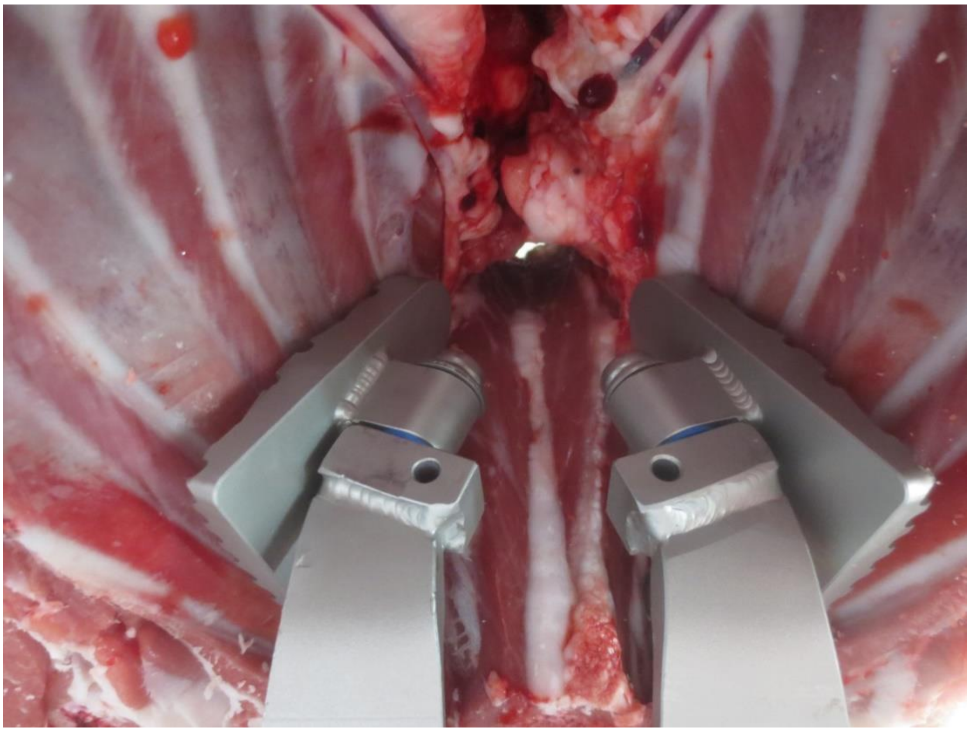

Fig. 54: Example internal clamps concepts under test by Scott Automation

7 Key messages

This project aims were to lower implementation cost of this system compared to the Scott LEAP V which makes this an ideal solution for small to medium scale food processors. Consistency and quality of yield provide a clear economic benefit to the customer. Social and sustainability benefits include a key emphasis placed on operator safety while improving on production. Due to the manual nature of the task, requiring repetitive motion and the need to work around hazardous meat processing bandsaws, the ability to have the operator out of harm's way provides an additional benefit in terms of Workplace Health and Safety. This is in light of preventing bandsaw injuries therefore reducing a significant impost on Australian red meat processing companies, including reducing the cost and reliance on skilled bandsaw operators. The solution will continue to underpin the quality associated with Australian red meat processors in the presentation of further processed meat cuts.