Final Report

AMPC
AUSTRALIAN MEAT PROCESSOR CORPORATION

Carcase Marking

Carcase Marking Stage 2 – On Plant Proof of Application (Lamb) Under Provider Supervision

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1.0 Executive Summary

Recent advances in sensing technology and vision analysis methods have given rise to the opportunity for lamb carcases and primals to be measured and assessed objectively as well as accurately for valuable traits and measurements. This is particularly important with the variable nature of lamb carcases and primals to ensure that maximum value can be attained for the producer, processor, retail butcher and consumer.

Scott and AMPC have a strategic plan to leverage carcase marking to both reveal (to human operators) as well as translate the information and measurements attained by advanced sensing equipment in a manner that will allow downstream processing to take advantage of this information that otherwise would be hidden/invisible or not available where information is lost through a break in the chain of traceability. AMPC “Advance Manufacturing” strategy carcase optimisation theme is summarised in the following excerpts from AMPC.

Figure 1: Excerpt from AMPC “Advance manufacturing – Carcass Optimisation” summary document

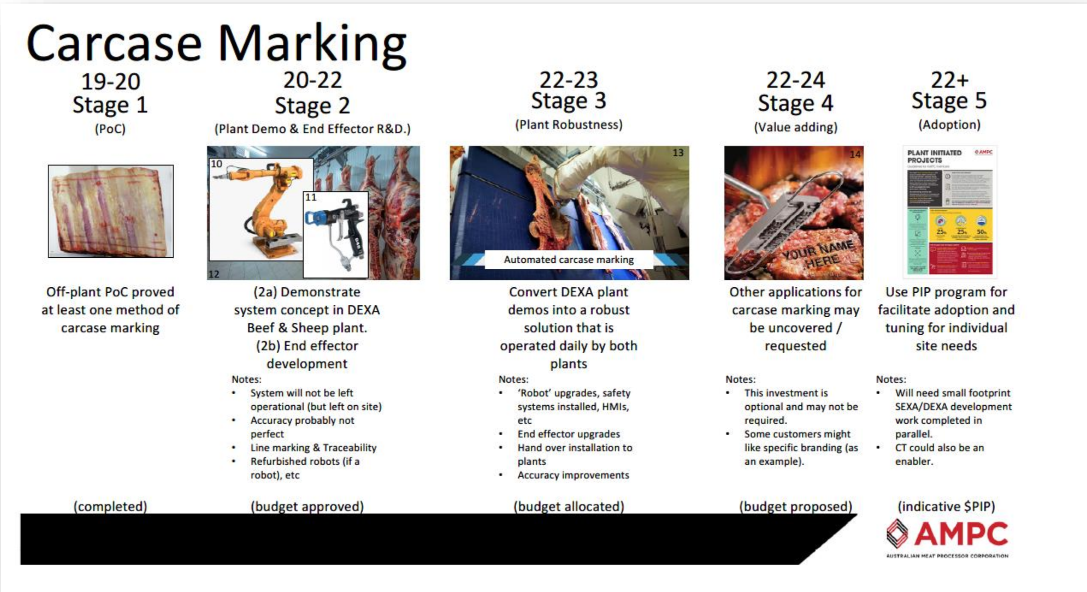


Figure 2: Excerpt from AMPC “Advance manufacturing – Carcass Optimisation” summary document

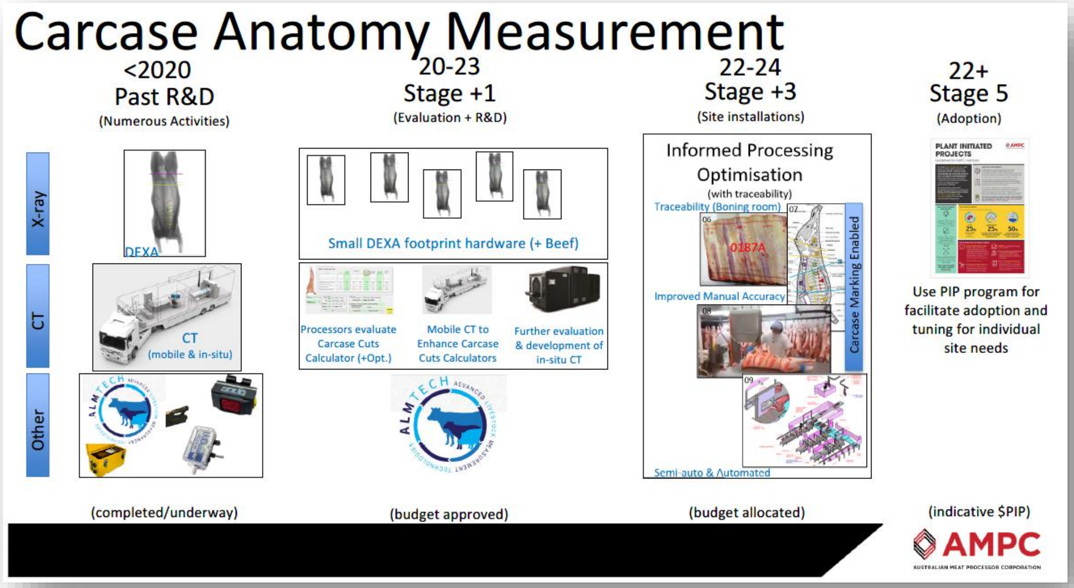


Figure 3: Excerpt from AMPC “Advance manufacturing – Carcass Optimisation” summary document

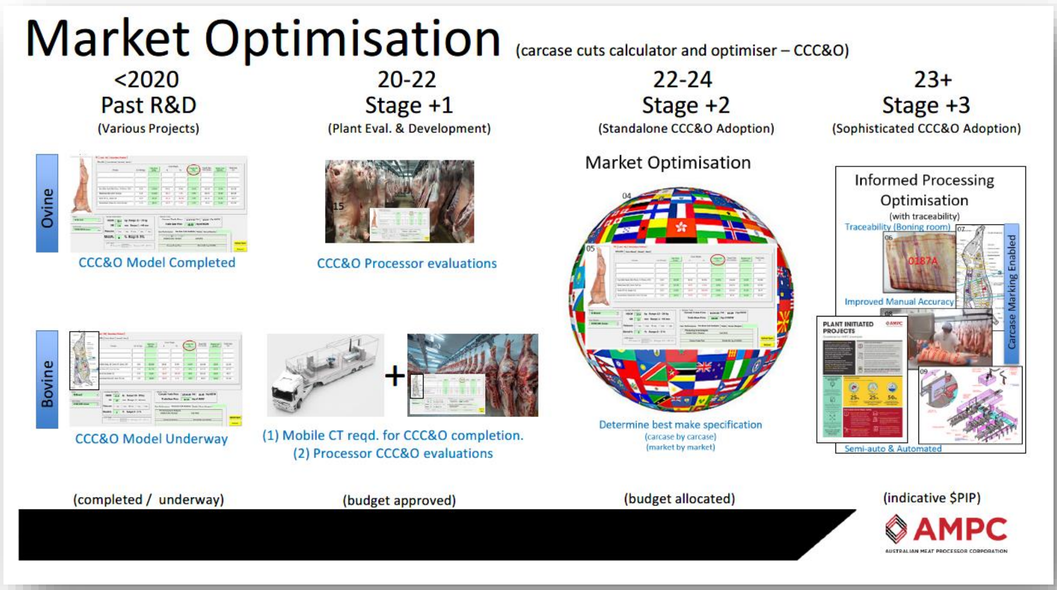


Figure 4: Excerpt from AMPC “Advance manufacturing – Carcass Optimisation” summary document

This project is a “proof of application” as part of AMPC carcase optimisation strategy - Stage 2”, under provider supervision, for demonstration of automated carcase marking on the visible external surface of a lamb carcase to reveal and translate advanced sensing measurements and information. As an early-stage discovery project it was endeavoured to use an existing sensing device with cheap and accessible hardware in a manner that was temporary and had only sufficient capability to demonstrate the concept of marking but without the expense of refining the measurement system or tuning the marking system for optimal performance.

As a well understood beneficial use case, in this project, a pre-rigour dual-energy x-ray absorptiometry (DEXA) sensing machine was used to derived cut positions that were then transferred as a visual marking to the outside of the carcase by way of demonstration using automated marking. An existing processor (host site) hot floor DEXA objective carcase measurement (OCM) machine was used to generate the data and demonstrate marking for the purposes of assessing both the feasibility and opportunity of carcase marking for practical applications within a processing environment such as guiding manual primal forequarter separation from the lamb carcase. Forequarter separation is defined as a single cut plane that passes through the spine at its junction with the fourth rib thereafter following the top of the fourth rib from the dorsal to the ventral tip of the fourth rib. The cut marker is sub surface and therefore not visible to the naked eye. Also important in this use case, as a pre-rigour sensing machine, the DEXA scanner can attain valuable information such as meat yield characteristics for every carcase that are used for primary sortation of carcases and direct feedback to producers (while the carcases are still traceable directly to individual suppliers). The same sensing device can attain additional valuable information such as primal separation cut lines that are not used until post rigour, and as such, are affected by movement of the carcase during rigour as well as being lost if/when traceability of the carcase is disrupted. It is anticipated that visual marking will overcome many of the significant challenges of taking measurements on the upstream processing line and using these measurements for downstream processing decisions.

To achieve the desired outcomes for Scott and AMPC key objectives, specific enabling x-ray sensing hardware was implemented at the processor host site. This upgraded the installation from OCM-only specification to the current Scott dual view DEXA x-ray arrangement which enables the system to extract sub-surface (internal) carcase primal separation cut lines based on anatomically bone defined cut specifications. This information is generated by way of a three-dimensional cut plane that intersects skeletal features hidden within the carcase tissue and invisible to the human eye.

This advanced sensor was coupled with an automatic spray marking system that was designed, built, and installed at the host processor in a manner where trials could be performed, and the unit dis-established without disruption to existing infrastructure or processing. This automatic spray marking system was designed to allow quick, temporary installation that did not damage existing equipment or plant.

To visualise the cut plane on the carcase a visible ink line is printed on the exterior surface of the lamb carcase where the cut plane intersects the exterior surface. This enables the human eye to distinguish the measurements taken by the advanced sensing system that would otherwise be invisible by looking at the carcase.

As a proof of application demonstration, the marking was reasonably coarse and the measurements from the DEXA sensor were only roughly tuned to the special geometry of the sensing assembly. The automated marking was however useful in demonstrating that as a concept marking can achieve the key objectives in revealing and translating advance sensing data to downstream operations. Several key learnings that relate to both the quality of the marking as well as the method for applying the marking were learned. The beneficial use case targeted showed that the forequarter cut line can be identified by the human operator post rigour and used when sawing the cut on a traditional BladeStop™ with GloveCheck™ safe bandsaw. A number of improvements for this specific use case were identified and discussed further in this report as well as identifying a range of significant other opportunities that could be achieved with the refining of a system that can both mark accurately as well as deliver an improved mark quality including a thinner and more defined line. This is expected to open the door to a wide range of potentially beneficial uses.

It is recommended from the outcomes in this project that Scott and AMPC progress with the next stage of carcase marking which will refine the quality of the marking as well as develop a refined prototype for a defined beneficial use case that can operate either inline or beside line and start to attaining the benefits of this technology.

2.0 Introduction

Traditional processing of lamb carcases into wholesale and retail cuts has relied on operator assessment of traits and measurements to determine the specification and separation locations for each unique carcase. Inherently human assessment is limited to the visible and tactile features of the carcase, and furthermore, any observations made by a human are lost as soon as product traceability is broken. As a result, significant value is forfeited though lack of information at the location where processing decisions are made and human estimation.

Scott and AMPC have a strategic plan to leverage carcase marking to both reveal (to human operators) as well as translate the information and measurements attained by advanced sensing equipment in a manner that will allow downstream processing to take advantage of this information that otherwise would be hidden/invisible or not available where information is lost through a break in the chain of traceability.

Prior to this project, Scott had completed as a stage 1, a benchtop trial in the engineering workshop using a line marking spray head to assess if food grade ink could be sprayed in a consistent line on meat product and be visible to the human eye. The spray head was a hand operated “spray gun” adapted to a pressurised ink feed unit. The trials involved manual application at various speeds, spray gaps and coloured inks to ascertain if a solution was likely.

As a stage 2 development, leveraging the outcomes from the first stage, this project has been designed to demonstrate, in a cost-effective manner, trials of a line marking device, for a selected beneficial use case, to provide insights into how line marking can be applied with output from an advanced sensor as well as identify key challenges that need to be considered if a commercial application is to be implemented.

Recent advances in sensing technology have greatly enhanced the ability to measure valuable traits and features with accuracy and repeatability. In some instances, this information is used directly to sort and dissect carcases for example through automated cutting and chiller sortation. In a vast majority of cases the information is lost directly after the automated process or as soon as the chain of traceability is broken. It is also the case that the cost of automation to perform processing operations can be prohibitive for smaller operations where the operator is responsible for identifying and performing the critical cuts.

One such advanced sensing technology that Scott and industry have developed for lamb processing is the Scott DEXA for measurement of lamb carcase yield, skeletal geometric analysis, cut plane placement and lamb feature identification. There is ongoing work to further expand the capability of the system to measure further valuable traits. The information from the Scott DEXA system is currently used for carcase sortation prior to further processing, feedback of yield information to producers to drive breeding plans, calculation of total saleable yield and whole of plant efficiency measurement as well as accurate separation of the carcase into wholesale cut ready for distribution to retail cutting operations. DEXA sensing is able to measure traits and features that are not detectable or visible to a human.

The host processor for this project has a hot DEXA (located on the primary processing floor). It was determined that using this system would be a cost-effective way to demonstrate how effective applying marking is at this early stage in the process and for translating the information all the way through the processing facility.

It is proposed that placing a visible mark on the outside surface of the carcase at the point where information is attained will resolve the issues related to separation between sensing (data production) and locations where carcase processing occurs (data consumption) as well as where the cost of automation to perform the cutting is prohibitive for processors with insufficient throughput to justify the capital outlay.

3.0 Project Objectives

In delivering stage 2 of the AMPC carcase marking strategy this project is seeking an “On Plant Proof of Application” demonstration, under Scott technician supervision, of semi-automated carcase marking on the visible external surface of lamb carcases utilising a DEXA derived cut position. It is expected this will provide confidence with the practical feasibility of marking in an automated manner as well as insights into possible use applications and considerations that will influence the success of a commercial application with an advance sensing system into a processing facility.

3.1 Project Outputs

Specific outcomes from this project include:

1) "Handsfree" (semi-automated) spray marking of the forequarter removal cut position on a small selection (circa 5 - 10) of lamb carcasses.
2) Assessment of the practical feasibility, possible applications, and considerations for progressing with development of a first production ready system in the next stage of development.
    a. How effectively the mark can be applied automatically using an advanced sensing system (including what challenges/considerations apply)
    b. How effective the mark is at translating the cut position information through downstream processing operations.
    c. Human (operator) identification of the cut position mark and assessment of how useful the information is in guiding downstream manual processing of the forequarter removal.
3) Recommendations for stage 3

4.0 Methodology

The methodology for the design, build, commissioning, and trials was set out in the initial purpose and description of the project and was separated into two parts to cover two distinct, but related sections. The agreed methodology is given immediately below and is followed by further technical detail and outcomes from the design and commissioning phases.

Part 1: Hardware required to extract cut line information from the DEXA unit

Install and commission required x-ray hardware enhancements into the host processors Hot DEXA machine:

- Latest Scott design Phase 2 DEXA x-ray hardware arrangement for cutline measurement.
- Installed and commissioned (please note that installation and commissioning did not extend to include refinement of the cut plane accuracy to the same level as when a Scott Primal machine is installed. This is not anticipated as necessary for the objectives of this project).
- Instate software in the DEXA to start outputting cut lines for standard Scott LEAP system cut specifications (based on standard AUSMeat bone-in cut specifications).

This hardware enables the DEXA machine to measure cut lines (used to drive primal and middle bone-in carcase breaking). It is noted that using data measured on the primary processing floor (prior to carcase chilling and rigour) for chilled carcase cutting has not been implemented to date given the challenges in translating the information through the plant and the unknown movement in the carcase that occurs during rigour. (this is one area anticipated to hold significant benefit from this marking technology if successful) It is also noted that the processes of calibrating the DEXA for accurate cut line data is specific to when a Scott Primal machine is installed or when putting a system into commercial operation. This finer level of tuning is not necessary for the objectives of this project and were therefore not attempted. As such the marked line is not mm accurate to the precise cutting line and is “close only” for this sensing system for the purposes of this trial work.

Part 2: Design, build and trial carcass marking setup. Note that Part 2 was progressed in parallel to Part 1. Part 1 is necessary for Part 2 to be effective.

- Mechanical and electrical design of a marking apparatus was completed with sufficient detail to enable workshop build. Detail design and drawings are not required for this stage of development and would add un-necessary cost.
- The marking unit was built in the Scott workshop in New Zealand and tested to ensure it was readily able to deploy and trial at site. A formal factory testing and refinement was not necessary and would have incurred un-necessary cost, however the system was setup and run in the Dunedin workshop to reduce risk of site deployment. The basic unit included (on each side of the carcase):
    - A two linear axis manipulator being driven off the information from the advance sensing system (DEXA).
    - A spray head and ink based on the unit trialled in stage 1 of this development.
    - Two basic laser arrays with a “HD webcam” to verify marking heights on the back and brisket.
    - All the above is designed to either self-support from the floor or mounted to wall by suction cups so that the host processor system can be repaired to “as new” when the trial completes.
    - A Small electrical enclosure was designed to hold a PLC, servo gear, electrical switchgear, power and communications equipment.
- Control of the system required the following code be developed:
    - PLC code to control the marking head and perform basic communications with the advance sensing system (DEXA)
    - Communications protocol with the DEXA unit to get RFID, any carcase cut info available and carcase position.
    - Code to co-ordinate the linear servo axis manipulators, laser depth profile and spray trigger.

- A PC was setup with a HD webcam to verify height measures of the semi-automated marks.
    - The project loaned an existing PC free issue by Scott.
    - The project loaned a webcam with sufficient resolution to see markings and laser lines sufficiently to verify height.

- Install and trials were
    - Conducted on the host processor site over a week (Saturday through to Friday).
    - Setup occurred on a Sat/Sun outside of production where necessary work was completed to get the marking hardware working and talking to DEXA.
    - Product trials occurred during the week at intervals that coincided with production and carcase availability.

Remove and make good.

Part 1: Design and installation details

The Phase 2 DEXA in this project is designed to deliver 3D cut line information with an accuracy of +/-20mm based on the standard mathematical modelling of the x-ray hardware geometry. It was noted that tuning requires significant scans of carcases, cutting and feedback to refine the micro-discrepancies in theoretical and actual geometries. There was no need to perform this tuning to achieve the objectives of this project.

A second x-ray tube was added to the x-ray assembly. The mechanical design comprises components required to mount the additional x-ray tube and auxiliary equipment.

Part 2: Design and installation details

1. Design of carcase marking setup.

The design of the carcase marking setup consists of three elements:
1. Mechanical supports
2. Spray equipment
3. Verification equipment

The mechanical supports have been designed in such a way that they do not damage existing floors and wall panels. Therefore, vacuum suction pads are being used (no bolting required). The other advantage is to attach and remove the mechanical support structure quickly.

A detachable servo driven gantry is with spray guns which can be moved in and out horizontally. The design includes the mounting of a distance sensor so that the spray head can be positioned relatively to the carcase.

The design for the verification equipment comprises mounts for a laser scanner and a camera allowing a visual inspection after the marking. A suitable laser scanner and camera have been selected.

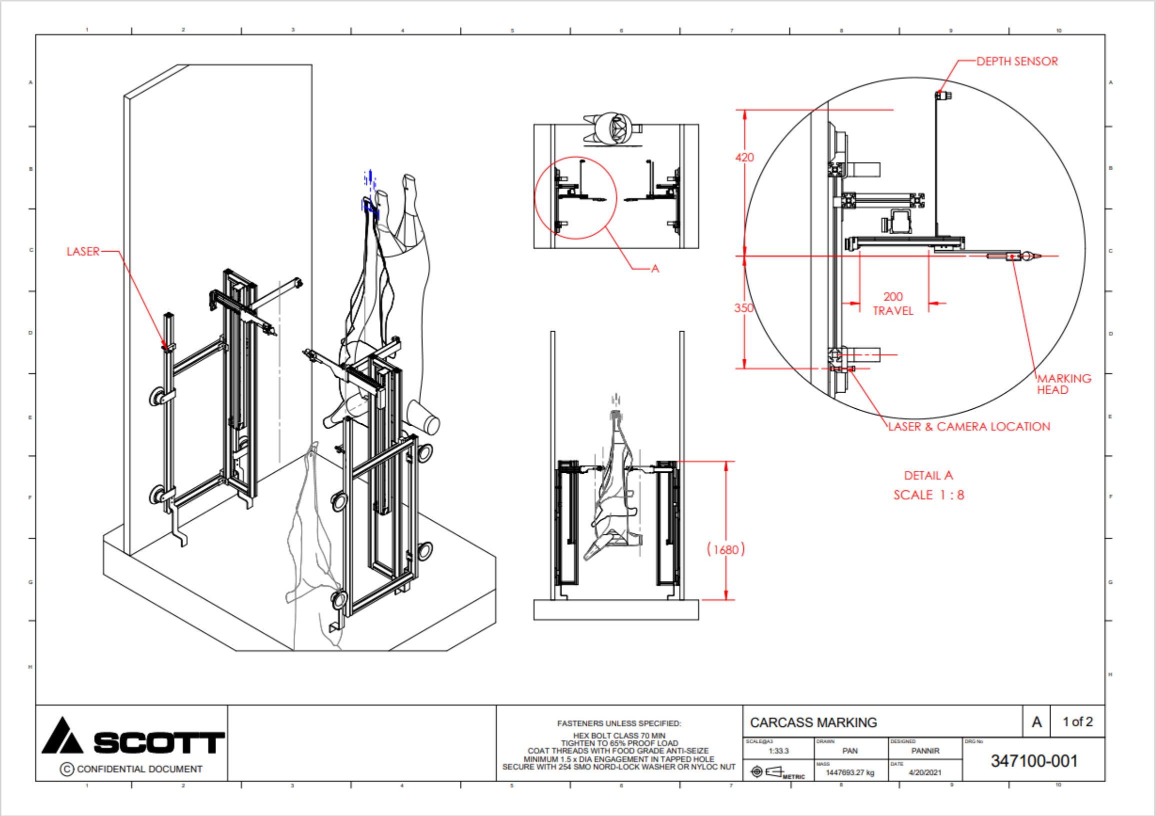
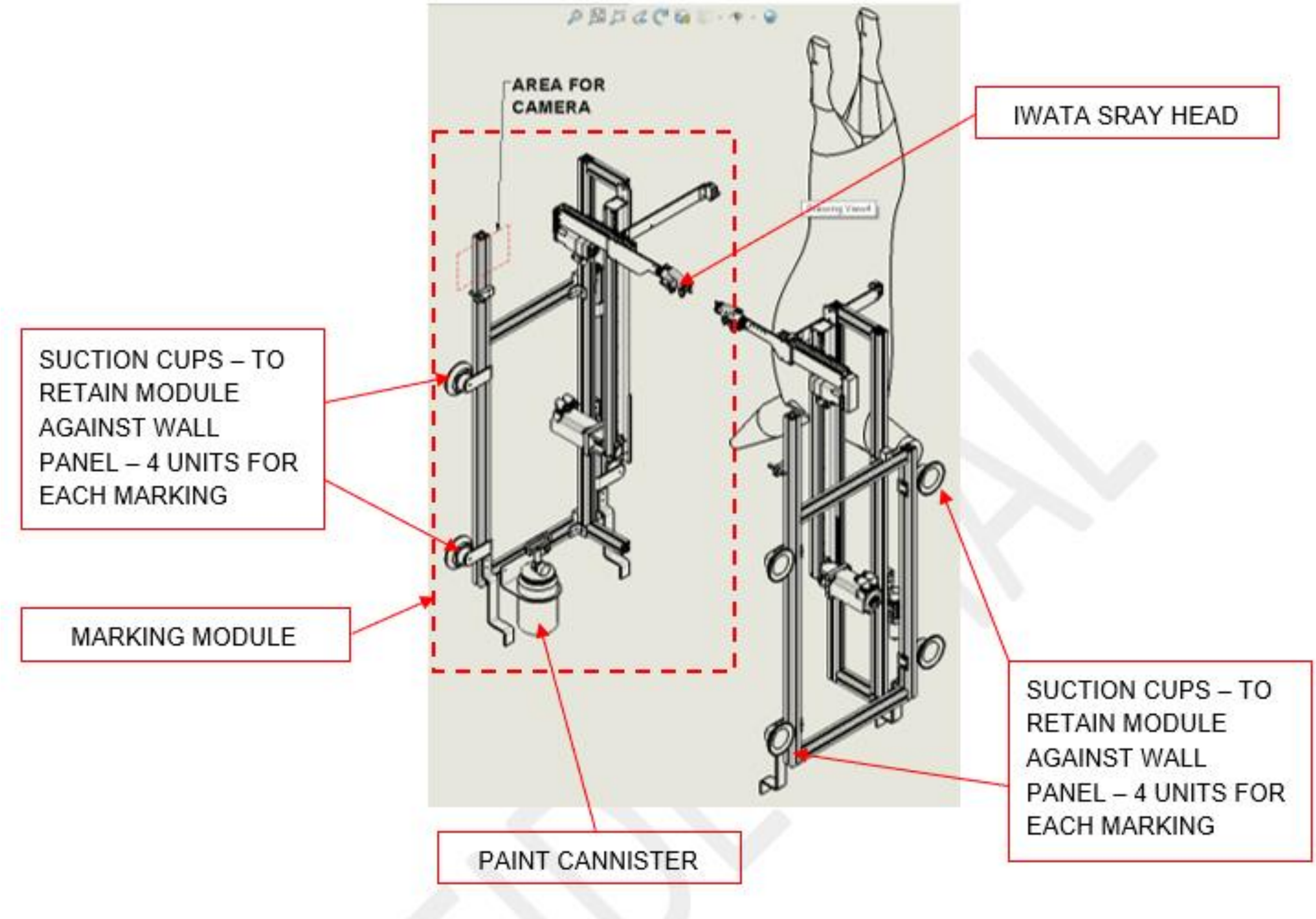


Figure 5 - Carcase marking assembly drawing no 347100-001

Based on the design principals, the following marking assembly was developed and built.



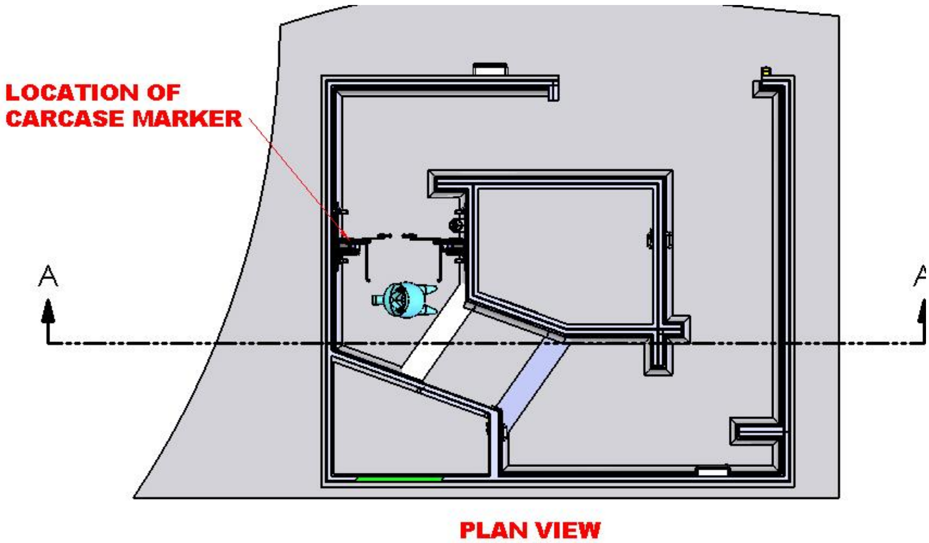


Figure 7 – Plan view of carcase marker

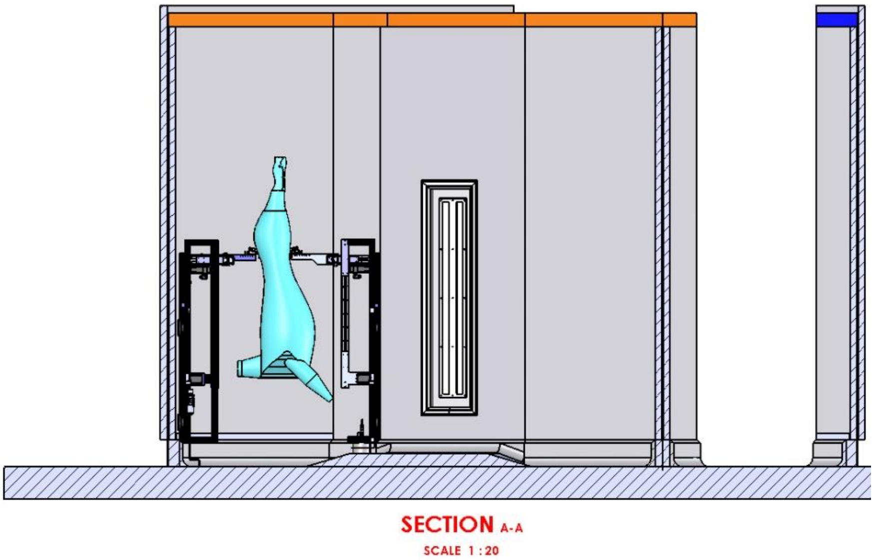


Figure 8 – Cross section of spray marker in DEXA room

Below are photos taken from assembly and commissioning of the spray marking system:

Figure 9 – Paint Cannister

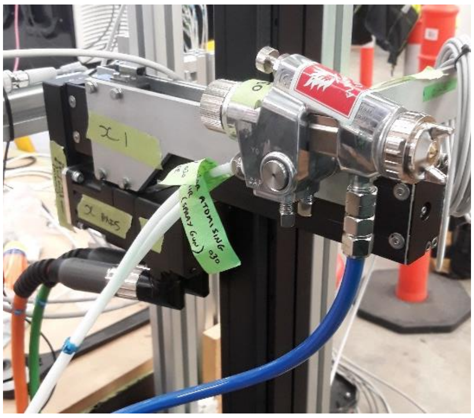


Figure 10 - Spray

*Figure 11 - W*all suction pad

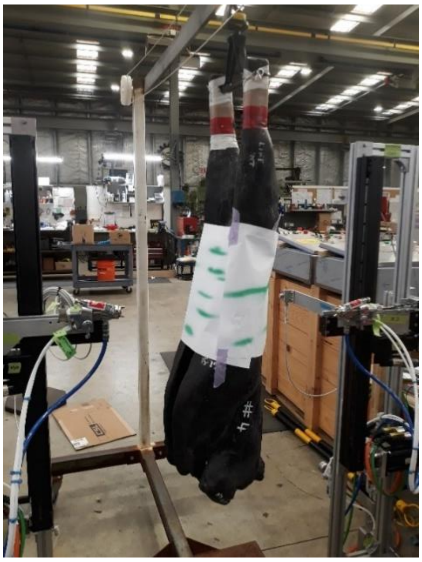


Figure 12 - Marking testing

Figure 13 - Camera

Figure 14 - Rear view of suction pad

Observations during commissioning of assembly in the Scott workshop

1. It took some time getting a thinner marking line due to variables such as air pressure, spray gun fanning and paint flow delivery. These were adjustable and setup relative to our workshop environment there will be site considerations and require site specific tuning relative to humidity, temperature, and air flow (if any).
2. Further fine tuning of the spray heads might be required during commissioning at the host processor site.
3. Setting up the position relative to the meat rail will be necessary on site (height and width). We simulated as close as possible to the dimensions that will be on site, height of the rail etc with our mock up in the workshop.
4. An encoder link to a pulley was used to simulate the position of the Carcass along the imaging chain. While on site we will rely on exchanged data between the DEXA PLC and the Carcass marking PLC. This setup will use produce/consume tags, and this is known therefore the code has been developed to be ready for this.
5. All data transfer from the vision PC results (cut height, pitch angle) will transit through the DEXA PLC before being used for carcass marking, the cut result needs to be valid for carcass marking to be accurate.
6. The length of the marked line will need to be defined on site relative to the speed of the chain, we simulated a carcass travelling through the spray area in order to get a line that is visible for cutting to be referenced.
7. Laser distance sensor will need to be tuned for the environment on site.

Milestone 6

X-Ray Vision PC Code and Hardware Upgrade

The upgrade needed the following changes to the system:

- Installation of hardware in the PC to monitor the motion of the chain.
- Updating the software to the latest version that can support the rotary shutter and the combined DEXA and cutting analysis.
- Changing the communications protocol with the PLC to the latest version.
- Recalibration of the geometry of the system.

The hardware and software upgrades to the system described above were implemented without significant issues beyond those normally expected during commissioning. The DEXA hardware upgrade was applied on the 23rd of May.

Murdoch University provided an interim recalibration of the analysis that was installed at the end of the 26th of May. Murdoch is working on a full recalibration using a new algorithm that is less prone to these changes. The affected results were recalculated on the 27th and sent to the client to ensure they did not lose any data.

Observations during install and commissioning of Phase 2 DEXA solution

1. This is a washdown area and the prototype is not IP rated for a washdown environment, the equipment shall be covered before cleaning.
2. The original Controls Room is located approximately 40m from the install point of the carcass marking prototype and extra cabling might be necessary.
3. A remote access is required for the Controls Team and a connection to the existing system must be provided via a port allocation on the Ethernet Switch.
4. Carcass Marking prototype install time will be conditioned to the location of the new Controls ECC. Cable route from Temporary ECC to Temporary Servo and Controls to be considered and new penetrations and droppers may be required.
5. For the correct operation of the system decent, reliable, and dry air is required for the spray guns.
6. The laser array with camera is on both sides close to the exit of the x-ray room. Checking if the fact that the carcass turner is approximately in this area affects the camera and laser operation.

Installation and Commissioning

The spray marking equipment was installed over the weekend:

- Equipment temporarily attached to walls using suction cups
- 3 phase power, ethernet and air supplied to device
- Commissioned and tested using cold carcass. Paper towels were used to setup ink mark. Verified sprayer is marking in correct position
- Automatic sequence was successful, markers moved to the correct input height and X position based on the carcase profile

Due to wall width constraints, the spray marker was located on the first corner after the DEXA. Ideally the device would be installed around the corner above the safety mats as this would give more time to calculate the cut data. These walls however are too close together and the machine wouldn't have enough clearance to operate.

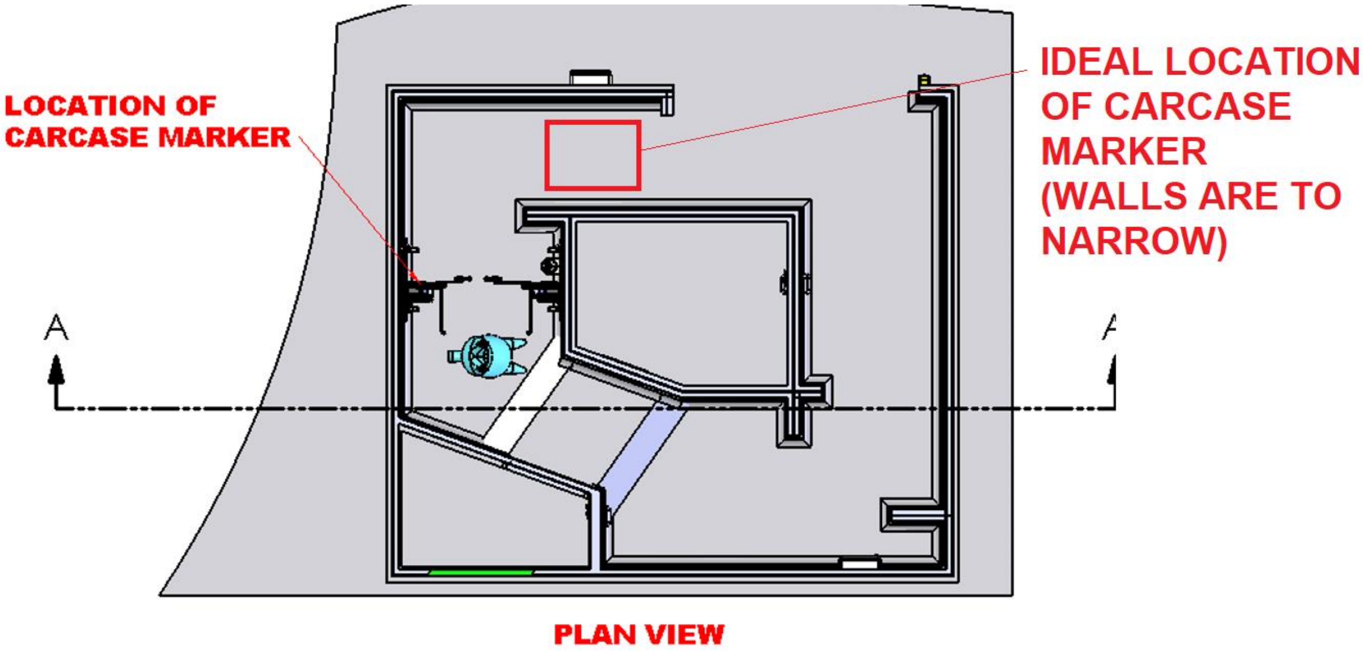


Figure 15 – Actual location of carcase marker vs ideal location

The carcase swing was significant as there is no stabilizer in this section of the room, especially at high speeds of 10 carcases per Minute. To reduce this swing, the chain was slowed down to 5 carcasses per Minute. Even at this low speed the swing was still high, a stabilizer will be needed for future machines.

Only a single spray mark point on the back and brisket could be made. This is due to the carcase orientation as it travelled down the chain and each side only having two axes of movement.

Figure 16 - LH and RH spray marking device installed

Figure 17 - Portable electrical enclosure with servo drives

Figure 18 - Initial ink spray tests without x-ray data

Figure 19 -Verifying mark position from the meat rail

5.0 Project Outcomes

Once the system was installed and the mechanical and controls systems commissioned, the next stage of trials used x-ray data to feed cut height and angle directly into the device to mark the cut lines. The two data points required were 'Cut Height' and 'Cut Angle' as seen in Figure . The spray mark location could then be calculated.

Due to processing delays, there was insufficient time to calculate and provide the spray marking PLC with this cut data before the carcase arrived at the machine. With the limited time available onsite, the x-ray data was manually entered into the code and was marked on the second rotation through the DEXA.

For future machines, the time it takes to process will need to be taken into consideration for machine location. An estimated time it takes to process the data is shown below:

1. Wait one chain pitch (914.5mm)
2. Save Images (0.5 Seconds)
3. Calculate DEXA and cut data (6 Seconds)
4. Wait one chain pitch for 'zones' to trigger the PLC communication (914.5mm)
5. Calculate spray mark position (1 Second)
6. Space for PE sensors (500mm)

- When the chain speed is **10** per Min (152.4mm/s), total distance travelled before data available is 3470mm
    - At this speed there may be enough space to put the device in the outfeed location, the wall width and carcase turners may cause issues.
- When the chain speed is **15** per Min (228.6mm/s), total distance travelled before data available is 4045mm
    - At this speed the spray marker will need to outside the DEXA room.

To verify the spray mark was in the correct place, a metal rod was inserted in between the 4th and 5th rib, at the rib angle until it came through the other side. If the metal rod and spray mark were in a similar location, we could verify the cut data and spray machine match.

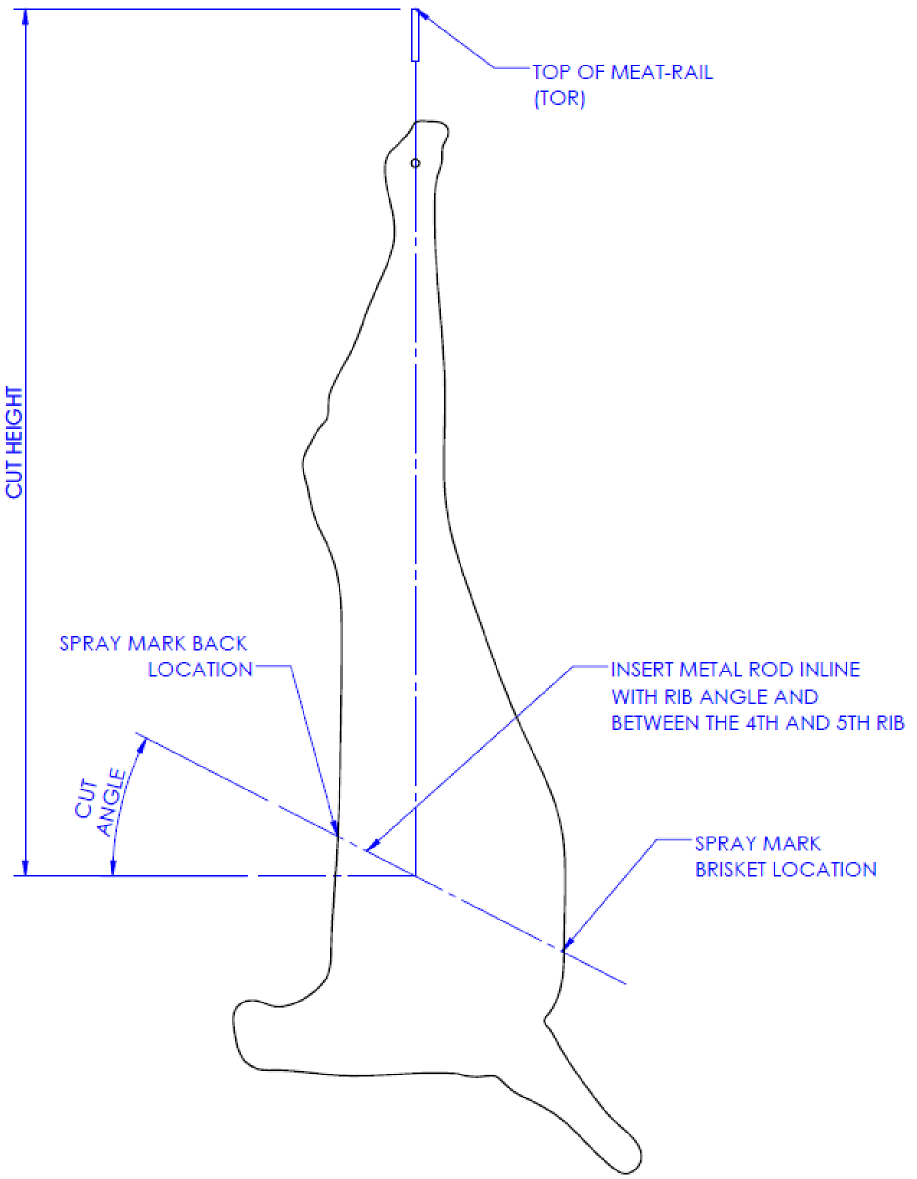


Figure 20 – Spray mark verification method using metal rod

Figure 21 - Carcase 1, metal pin aligned though the 4th / 5th rib, showing a very close mark. Approx 10mm from the pin

Figure 22 - Carcase 1, metal pin showing it between the 4th and 5th rib. This technique was done for all carcasses

Figure 23 - Carcase 2, metal pin aligned though the 4th / 5th rib, showing a close mark. Approx 15mm from the pin

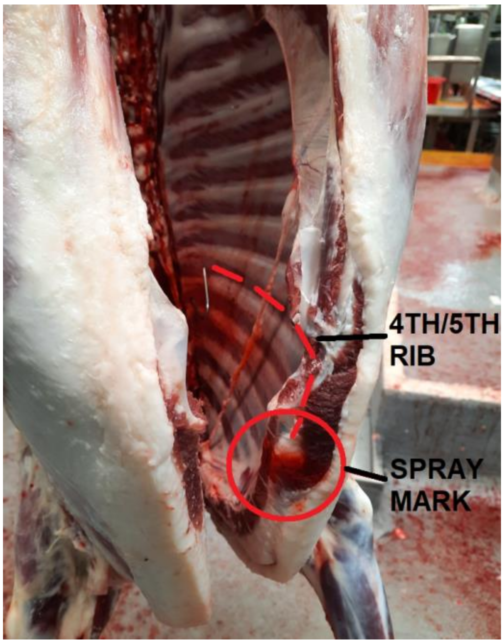


Figure 24 - Carcase 2, Ink mark on brisket. This mark lined up with the 4th and 5th rib intercostal

Figure 25 - Carcase 3, metal pin aligned though the 4th / 5th rib, showing a very close mark. Approx 5mm from the pin

Figure 261 - Carcase 3, Ink mark on brisket

Figure 27 - Carcase 4, metal pin aligned though the 4th / 5th rib, showing a very close mark. Approx 5mm from the pin

Figure 28 - Carcase 4, Ink mark on brisket

From these results above, we can conclude that the data from x-ray is able to provide a good location of the 4th and 5th rib junction. The pin showed most marks were within 10mm of this position. Further improvements on the calculations and spray mark width will be required to improve the accuracy from 10mm to 2-5mm.

Hot to cold marking trials

To understand the way carcass marking changed shape from hot to cold, measurements were taken before and after chilling.

Using a laser lever, the distance from the meat-rail to the centre of the spray mark on the back of the carcase was measured. The height of the brisket mark was also determined using the same line. These measurements were repeated after 17hrs in the chiller and any changes in measurements was recorded. *Figure* shows the process used to measure and check the spray mark. 3 hot carcases were measured for this trial.

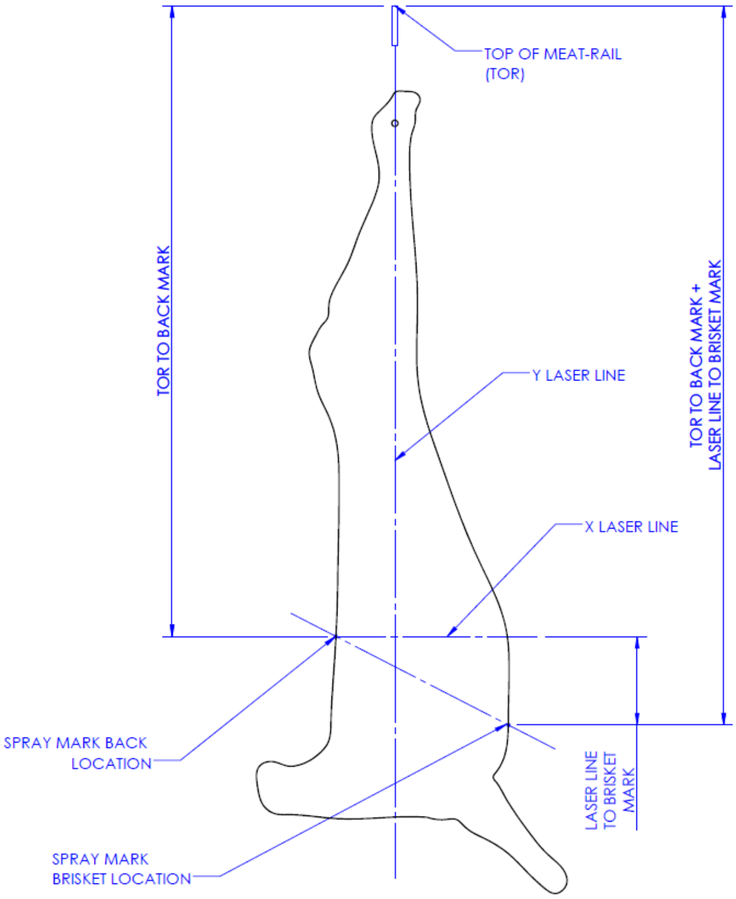


Figure 29 – Diagram showing process used to measure movement from hot to cold. Laser level was lined up with the back spray mark and measured to the meat-rail

Figure 30 - Carcase 1, Hot

Figure 31 - Carcase 1, Cold (17hr)

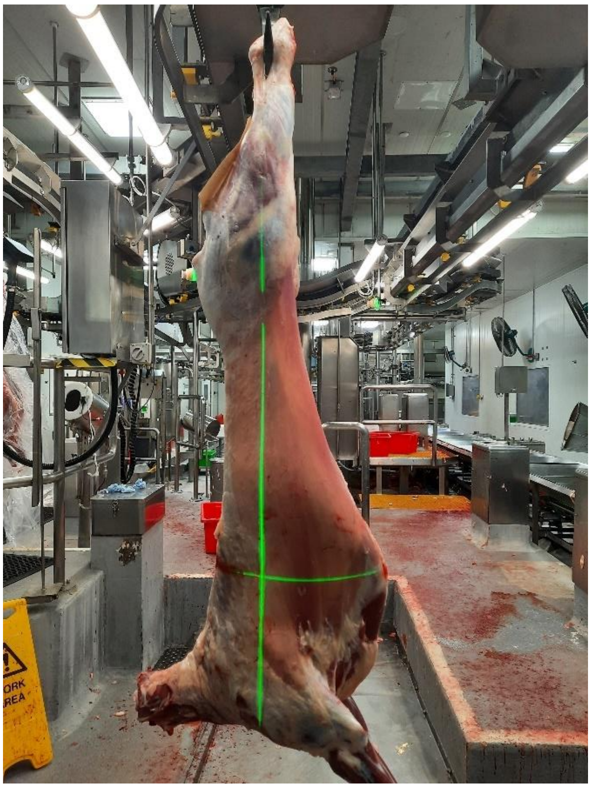


Figure 32 - Carcase 2, Hot

Figure 33 - Carcase 2, Cold (17hr)

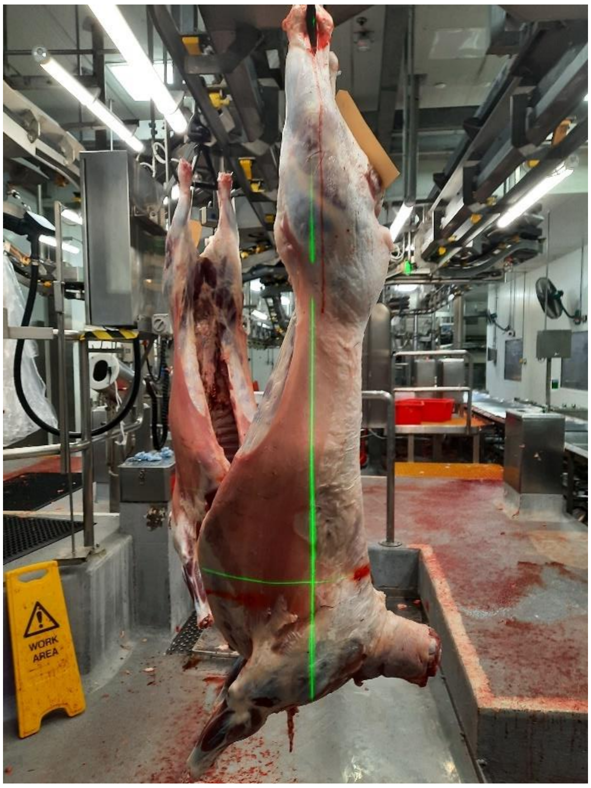


Figure 34 - Carcase 3, Hot

Figure 35 - Carcase 3, Cold (17hr)

It was found that the carcase shrinks by a small amount for some when it goes through the chiller. The results are not consistent however as one carcase showed no movement.

Spray mark cutting trials

Two carcases that were sprayed using x-ray data were cut using a bandsaw. This checked the spray marks' ability to assist the sawman to cut between the 4th and 5th rib. The following is a list of observations form these trials:

- The current process for cutting the forequarter involves the sawman opening the brisket, looking into the cavity, and finding the 4th and 5th rib junction by eye. From there a cut is made in the approximate location. With this method it is very difficult to hit the rib junction as he only has a few seconds to make a judgment call on where to position the carcase and cut. Having a line to follow would benefit the sawman's ability to hit the correct position.

- A line had to be drawn from the back mark to the brisket as the sawman couldn't see the back mark when the carcase was lying on the table. Future spray markers need to have this capability to make this a feasible solution

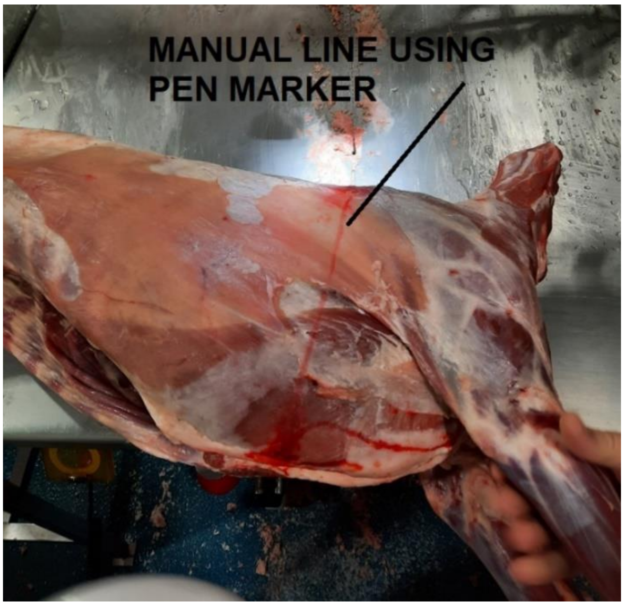


Figure 36 – Carcase with manually drawn line between back and brisket mark

- It was difficult for the sawman to align the cut plane of the saw to the line of the mark. A visible laser line attached to the bandsaw that showed the cut plane would assist the sawman to align both the laser and the cut line. Verification will be needed to ensure this laser line does not affect the safety function of the blade-stop camera.

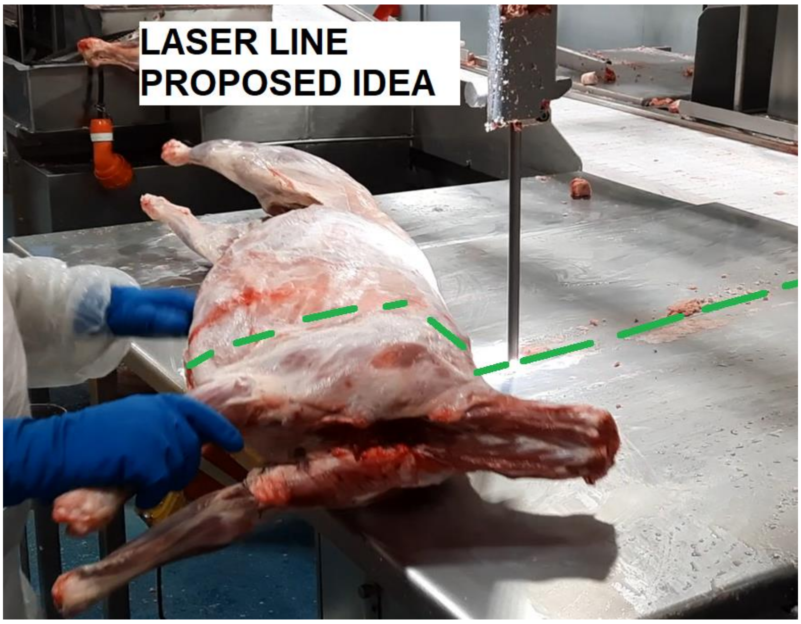


Figure 37 – Carcase on bandsaw table with proposed laser line drawn in

- The spray marks were roughly in the correct position. If the cut was positioned more towards the centre of the mark, it would have been closer to the 4th / 5th rib junction.

Figure 38 – Carcase post cut

- Only one side of the carcase needs to be marked. The other side of the carcase will be obstructed from view by the bandsaw table. This will save on cost, complexity, and machine size inside DEXA room.

Spray Mark Quality

The spray marker used was an automated spray-painting head, intended for robotic applications such as painting car bodies. Via tuning of the needle valve and air pressures, the line thickness was reduced to approximately 20mm. With research into existing spray markers, it was discovered that this line could be reduced to about 3mm if a different spray marker is used.

Figure 39 - Example photo showing an REA JET spray marking a line onto a belt.

The ink used was MEFE Halal Food Grade Red Ink. It was alcohol free and used sugar and die to mark the fat cap. The ink worked well and was unable to be rubbed off immediately after application on hot carcases. The effect of the carcass washer and electric meat stimulator was not tested.

Feedback from site showed that the red ink had little effect on the appearance of the product. The red colour mimics muscle and blood, making the marks look natural.

The Ink adhered better to hot carcases than cold. This would be due to the fat cap remaining soft and porous when freshly slaughtered, allowing the ink to penetrate deeper into the fat cap. With chilled carcases, the fat cap became hard and less porous, resulting in ink dripping off at certain points.

Figure 40 - Spray mark on cold carcase, Ink running off fat cap

Figure 41 - Spray mark on hot carcase, less susceptible to ink running

Future Recommendations

- Spray mark from the back to the brisket using a continuous line, on one side only.
- Future machines will need a carcase stabilizer, like the one used for DEXA scanning. This will greatly improve the spray mark quality and accuracy.
- Implement a laser line on the bandsaw to help the sawman line up the cut plane with the spray line.
- Use a more suitable spray marking device to produce a 3mm line. The current Iwata spray gun produces a 20-25mm thick line.
- Improve the x-ray software to produce the cut heights and angles before the carcase reaches the spray marking device or move the location of the device further away from the scan. A separate cell in the chiller could be a viable solution.
- Redo the carcass movement trials (hot to cold) with a larger sample size and a more accurate and thinner scribe line. Measure the movement at more intervals.
- Check the impacts of the carcase washer and meat stimulator on ink mark quality.

6.0 Discussion

Due to the impact from global logistics, resource availability and the pandemic, delay with the freighting of the equipment occurred and scheduling of resources coinciding with production requirements delayed the project. However, the install and trials of the carcass marking have now successfully completed and the marking system has been uninstalled from site as planned.

Carcass marking trials at the host processor site successfully proved the process of marking the cut plane in an automated manner using two externally visible spray mark points on the back and brisket of the carcase. There were a number of key insights attained that will provide guidance for further work and considerations for carcase marking to be successfully implemented as an automated method for recording and translating the output from advanced sensors.

Most notable of the learnings and insights include:

1) Sensor to Marking actuator physical separation

A few factors come into effect when positioning the marking hardware relative to the advance sensing hardware.

The time it takes to post process, communicate, and act on the output of the advance sensing system is critical in determining the separation distance between the sensor and the marking apparatus as well as the operating speed achievable by the two systems combined. Notably if the primary function of a system is to provide low throughput processors with a means to translate information to downstream operations, then the speed of the system will be slow, and the location used in the trials will be sufficiently spaced to allow data transfer to occur. For higher throughput processors the speed will be higher and therefore the separation requirement greater. This may require a DEXA enclosure with sufficient space designed to allow the carcase marking equipment to be positioned further apart from the x-ray sensing hardware.

Having the marking equipment inside the same enclosure as the advance sensing system ensures that the carcases are tracked reliably to ensure data integrity, the orientation of the carcases is maintained, the stability of the carcases is controllable, and the safety of moving hardware is ensured with without significant machine cell layout and footprint to house the equipment separately.

A further benefit of having the marking equipment inside the DEXA enclosure is to ensure that no post DEXA processing occurs prior to marking which could erode the accuracy of the DEXA measurements.

2) Ink and spray head selection

It was noted that the spray head selected based on the results from stage 1 and a commercially developed spray applicator for industrial use produced a spray mark that was wider and less refined than would be optimal for the use case of guiding separation of the forequarter from the lamb carcase. It was discovered through commissioning that the spray line quality was highly sensitive to how far the head is offset from the product surface, the texture of the surface, the characteristics/consistency of the ink at different temperatures, the feed rate of the product compared to the flow rate of the ink, the cleanliness (and build up) of the spray head.

Off the shelf red ink was used based on its acceptance as a food grade product for use on edible product. The ink is easily visible at with the line marks that were applied, and it was shown by manually applying ink that thinner more refined lines remained highly visible and identifiable by the operator.

Surprisingly, although visible ink line remained after the cutting process, general feedback asserted that the remaining line would not adversely affect the saleable value of the product nor worry the processors clients.

3) Operator using marked lines for Forequarter separation

When the automatically applied brisket and back marks were presented to the human operator to use as a guide when sawing the Forequarter from the carcase the main feedback included:

a) The marks were easily identifiable and that red marks were clearly distinguishable.
b) External marks still required the human operator to infer/translate the overall cut path through the entire carcase as well as try and align this with the saw blade as the carcase is moved through the saw past the blade. This appeared to be difficult to perform both these actions albeit it was not ultimately clear if this would become a learned behaviour or would remain challenging as operators become more familiar with the markings. It was ascertained through observation that currently the operator pulls the brisket apart to view inside the rib cage before counting the ribs to the fourth rib, aligning in mind's eye the location where the 4^{th} rib connects with the spine, observing roughly the angle of the rib before then taking aim to pass the location identified at the spine directly towards the saw blade and then manoeuvring the carcase to match the observed rib angle.
c) For these reasons, it was recommended that
    i. A laser be setup on the saw to visualise the path that the carcase would take relative the saw blade as the operator moves it through the saw. (This is already a stock supplied option for the Scott BladeStop™ and GloveCheck™ safe stop band saws.)
    ii. When marking the carcase using the advance sensor the mark should extend the full length between the brisket and back of the animal

4) Effectiveness of translating information throughout the processing operations

Marks were applied in a semi-automated manner on the primary processing floor prior to rigour and entering the chiller. It was noted that the marks were very quick to set permanently on the surface of the carcase whereby in the time it took to walk inside the enclosure and meet the carcase directly after spraying had occurred it was difficult to rub, smudge or deform the marks using water, towel or by hand.

When observed post chilling the marks remained un-disturbed.

This indicates that spray marking the carcase is reliable means to translate information throughout the process without risk of losing or distorting information in processes that involve physical contact, water or cleaning.

It was notes that in instances where carcases were to be heavily trimmed that the surface mark would not survive cutting or knifing the external surface due to the relatively shallow penetration of the ink.

Using metal rods as a guide, it was shown that the spray mark was within 5 – 15mm from the 4^{th} and 5^{th} rib cut plane.

5) Effectiveness of applying the mark automatically

Automating the marking process has a number of challenges that were identified in this stage of development. The spray mark application proved highly sensitive to spray gun offset from the carcase outside surface, the texture of the carcase (as it was noted that some carcases that received a mark when freshly slaughtered gave a different quality of line than those that had chilled for example), the characteristics/consistency of the ink at different temperatures was noted as the setup of the spray head was conducted at various different time where different temperatures and humidity) were experienced, the feed rate of the product compared to the flow rate of the ink proved critical to line quality, the cleanliness (and build up) of the spray head changed with use and had an impact on the quality of the marking.

7.0 Conclusions / Recommendations

Carcass marking trials showed that using x-ray data and a two-axis spray marking device can produce a cut plane accurately between the 4th and 5th rib.

The MEFE Halal Food Grade ink worked well when sprayed and was unable to be rubbed off immediately after application on hot carcases.

Further developments for spray applications:

- The effect of carcase washer and electric meat stimulator.

Further development of the process is recommended to achieve a line that is more useful for the sawman. These key developments are:

- Change from single point to continuous line, only one side of the carcass need be marked as the other side is obscured when cutting on a bandsaw.
- Use a carcase stabiliser during spray application to ensure accurate spray application.
- Produce a thinner red ink line (3- 5mm).
- Ensure x-ray cut height and angle calculations are available when the carcase is at the spray chiller. This could be accomplished by (a) Improving the x-ray processing time in software/hardware or (b) moving the spray station further from the scan location.
- It was also proposed that a laser line at the bandsaw could aid an operator in “lining up” the marked forequarter cut point.

An additional aspect of the project was to establish any movement in the marks during chilling. This experiment found that in the data set gathered there was significant variability in the movement of the spray mark (relative to the meat rail).

Further research into the process of carcase movement during chilling would help gain an understanding of:

- How predictable is the movement during chilling? Could x-ray data from a hot carcase be used in the automated boning of the same carcase after chilling?

8.0 Bibliography

AMPC 2020, *Advanced Manufacturing - Carcase Optimisation (Processors)*, Not in publication. Summary document.

Scott 2019 - P.PSH.1204 Leap 4 Beef Marking Final Report, www.mla.com.au/research-and-development/reports/

9.0 Appendices

9.1 Appendix 1

Please refer to Scott/MLA project P.PSH.1200 for detail on stage 1 carcase marking initial investigation.