final report

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Beef Spinal Cord Removal – Development Trials MAR

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Abstract

MAR has been working with MLA and the beef processing industry to develop future automation strategies. The Beef Spinal Cord Removal system has been identified as being both viable commercially and able to fit within most processing facilities. The benefits to processors and the wider industry of automating the Spinal Cord Removal Task are seen as the following:

- Address shortage of skilled labour
- Eliminate OH&S risks associated with manual task
- Improve downstream processing
- Consistently improve Hygiene
- Reduced contamination

MAR researched the available manual tools that are used for spinal cord removal and it was found that the most commonly used tool in Australia was difficult to adapt effectively to a robot. An alternative High Pressure Water and Vacuum Removal tool was developed. Robotic trials with this tool were conducted which proved the concept of the tool but also highlighted that further work is required, mainly in the areas of visioning the carcass and tool compliance before the system would be accepted in the processing environment.

Executive Summary

MAR has been working with MLA and the beef processing industry to develop future automation strategies. The Beef Spinal Cord Removal system has been identified as being both viable commercially and able to fit within most processing facilities. The benefits to processors and the wider industry of automating the Spinal Cord Removal Task are seen as the following:

- Address shortage of skilled labour
- Eliminate OH&S risks associated with manual task
- Improve downstream processing
- Consistently improve Hygiene
- Reduced contamination

MAR researched the available manual tools that are used for spinal cord removal in Australia. Concerns were raised with regards to mounting this tool on a robot with regards to the accuracy required to locate the tool in the canal and possible damage to the tool should it not be located suitably or should it encounter a carcass side with a broken back. With this in mind MAR trialled removing the spinal cord and duramatta with high pressure water. Initial manual trials at Hardwick's meat works in Victoria provided enough positive outcomes for MAR to propose this as a possible solution. Discussions were held with APMC and MLA, the conversation discussed possible concerns with regards to Food Safety, Market Access and Shelf Life of the product. It was acknowledged that:

- visual absence of spinal cord/duramata would be the key to the acceptance of any new process.
- recent trials had shown that the use of high pressure water left the carcase looking cleaner than current practices.
- containment and segregation from edible product of the water jet and removed spinal cord /duramata would be a key food safety concern.
- Negative impacts on shelf life are likely to be negligible given that the carcasses are already exposed to water from other processes particularly where spray chilling is applied
- The use of water in removal of bone dust may in fact have a positive effect on product presentation/shelf life.

As a result of this discusson a two pronged approach was used to allow investigation into multiple options for the removal of spinal cord.

1) Further development of the current high pressure water/ high vacuum tool. Further design focused on developing a method of containing the spray so that ultimately all the spinal cord, meninges and high pressure water were vacuumed away.

2) Develop a tool that uses the cutting tool that is currently commonly used manually and uses vacuum as a method of carcass stabilization.

Results of manual trials with these tools showed that it was difficult to adapt the manual cutting tool so that it would work effectively but that the High Pressure Water and Vacuum Tool showed potential. The HP Water and Vacuum tool was adapted for mounting on a robot and trials were conducted with positive results. Videos of the trials were shown to industry expert John Hughes and Graham Treffone from JBS. John and Graham raised concerns with regards to

- splash onto the other areas of the carcass
- high pressure of the water being forced into the meat through the nerve canals
- the ability to present the side of beef in the correct position every time
- The speed of operation

However MAR believe that these concerns can be addressed with further work and would recommend moving onto Stage 2 as outlined in the Background section of this document, that of a PIP project.

Contents

1 Background

In most Australian Beef processing plants typically operating at 50-70 hd/hr, one or two labour units are utilised to remove the spinal cord. This task is generally performed manually using a powered spinal cord removal tool to remove spinal cord material over the length of the exposed beef side spine.

This Stage 1 tool development and trials for Automating Spinal Cord Removal is an essential step to ensure proof of concept and commercial viability of an automated system to perform this task. Based upon previous work and knowledge of the process, MAR's concept for Spinal Cord Removal will focus only on spinal cord removal after the carcass has been split. This will allow for stability of process, sensing and access to remove spinal material from the exposed beef side.

MAR has been working with MLA and the beef processing industry to develop future automation strategies. The Beef Spinal Cord Removal system has been identified as being both viable commercially and able to fit within most processing facilities. A robotic spinal cord removal system will also provide the ability to incorporate this technology with other automation such as trimming, fat removal and sani-vac operations. Combining these tasks and technologies within one operating cell in the future will provide reduced footprints and allow for common stabilisation and sensing technologies to be utilised for each task. All of which will provide significant cost benefit improvements by minimising hardware producing better paybacks.

This project will form Stage 1 of a 3 stage development process:

Stage 1 – MAR Beef Spinal Cord Removal Development Trials – *this project*

Stage 2 – Automated Beef Spinal Cord Removal, PIP project – FUTURE PROJECTS

Stage 3 – Commercial Availability of Automated Beef Spinal Cord Removal

2 Project Objectives

This project will address the key fundamentals for automating spinal cord removal by confirming spinal cord location, robot paths for operations and by developing and trialling a suitable spinal cord extraction tool robotically.

Technical challenges that must be addressed with the outcome of this project are;

- Ensuring tool is able to remove spinal cord material including duramata consistently throughout the entire length of the beef side spine.
- To ensure this SRM is disposed of correctly avoiding contamination during the slaughter process prior to inspection
- Ensure existing concepts for stabilisation and tool sterilisation are suitable for future fully automated systems
- To ensure spinal cord can be detected as a 3D profile accurately suitable for automation
- Alerting operator if spinal cord matter was not successfully removed, eg cycle did not complete.

Successful completion of this project will lead to development of a fully automated spinal cord removal system utilising 3D sensing and a spinal cord removal tool with vacuum extraction to clean and remove spinal cord material throughout the length of the exposed spinal cord robotically.

Specifically the objectives of the project are:

- To establish the best methods and tools available suitable for automating spinal cord extraction
- To confirm the best method of sensing spinal cord profile required for automating
- To design and manufacture an extraction tool system for robotic adaptation
- To perform manual proof of concept trials using the developed tool
- To perform robotically operated proof of concept trials using the developed tool
- To demonstrate the capabilities of the extraction methods
- The outcome of this project to enable next stage implementation of an Automated Spinal Cord Removal system

3 Methodology

The objectives will be achieved by completing the following milestones:

Milestone 1 - Investigate available spinal cord removal tools & methods

Milestone 2 - Design of tool & extraction for robotic adaption & trials

Milestone 3 - Perform 3D sensing trails to confirm best sensing method

Milestone 4 - Manufacture tool suitable for robotic adaption & trials

Milestone 5 - Setup MAR Robots, Controls & Software, supplied to project

Milestone 6 - Perform manual POC trials at a beef processing facility

Milestone 7 - Perform robotic POC trials at a beef processing facility

Milestone 8 - Develop a concept design for automated system

Milestone 9 - Detailed report & videos of trials

4 Results and Discussion

4.1 Investigation into currently available tools

A web search was conducted for spinal cord removal tools and revealed three main types:

- Vacuum tool
- Vacuum tool with external cutter (pneumatic and hydraulic driven)
- Vacuum tool with internal cutter.

1) Vacuum Tool

Both Jarvis and Kentmaster manufacture a simple vacuum tool (the Jarvis tool is shown below)

Fig. 1 Jarvis Vacuum tool

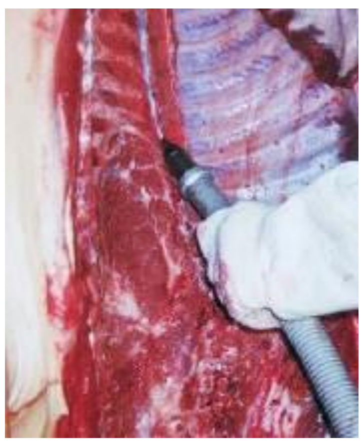

Fig. 2 Vacuum tool in use

2) Vacuum Tool with external cutter

Again both Jarvis and Kentmaster had versions of this form of tool, Jarvis with either a pneumatic or hydraulic driven motor, the Jarvis pneumatic tool is shown below:

Fig. 3 Jarvis pneumatic tool

Fig. 4 Pneumatic tool in use

Fig. 5 Jarvis Hydraulic tool

Fig. 6 Kentmaster Hydraulic tool

3) Vacuum tool with internal cutter

The image below shows the Bettcher Industries vacuum tool with internal cutter

Fig. 7 Bettcher Industries Vacuum tool with internal cutter

With this tool the vacuum pulls the spinal cord towards the circular blade that cuts and dislodges the spinal cord, sheath and other debris in the spinal canal while the vacuum conveys the trimmed material away.

Following the web search discussions were held with both suppliers of the tools and processors. Jarvis who supply the vacuum only tool along with the vacuum tool with external cutter were contacted and stated that the pneumatic driven tool had been trialled in Australia however the trials were unsuccessful due to the lack of power/ torque in the motor and the saw kept stalling. The hydraulic driven tool had also been trialled however currently no processors in Australia were using this tool.

Food Processing Equipment (FPE), the suppliers of the Bettcher Industries tool in Australia, were contacted and able to supply a list of processing plants in Victoria, New South Wales and Queensland that currently use the tool.

Contact was made with JBS Australia (Graham Treffone) and it was stated that the Bettcher tool was their preferred method of spinal cord removal, they had not had success with the Jarvis tools and there were concerns with the amount of bone dust that the Jarvis tools created as they ground out the spinal canal. With this in mind and the fact that no Jarvis tools are currently being used in Australia, a visit was made to the JBS plant in Yanco to view the tool in operation. The images below are from the site visit.

Fig. 8 Bettcher industries tool at JBS Yanko

Fig. 9 Bettcher Industries tool in use at JBS Yanko

Following this site visit and viewing of this tool in operation it was decided that it would be practical to develop an adaptor to allow this tool to be fitted to a robot. FPE were contacted and one of these manual tools was obtained.

4.2 Vision Trials

Vision trials were conducted using a Sick 3D Ruler camera. The results varied and it was shown that it was difficult to achieve useable data with the actual cord still present in the canal. The images below show the results:

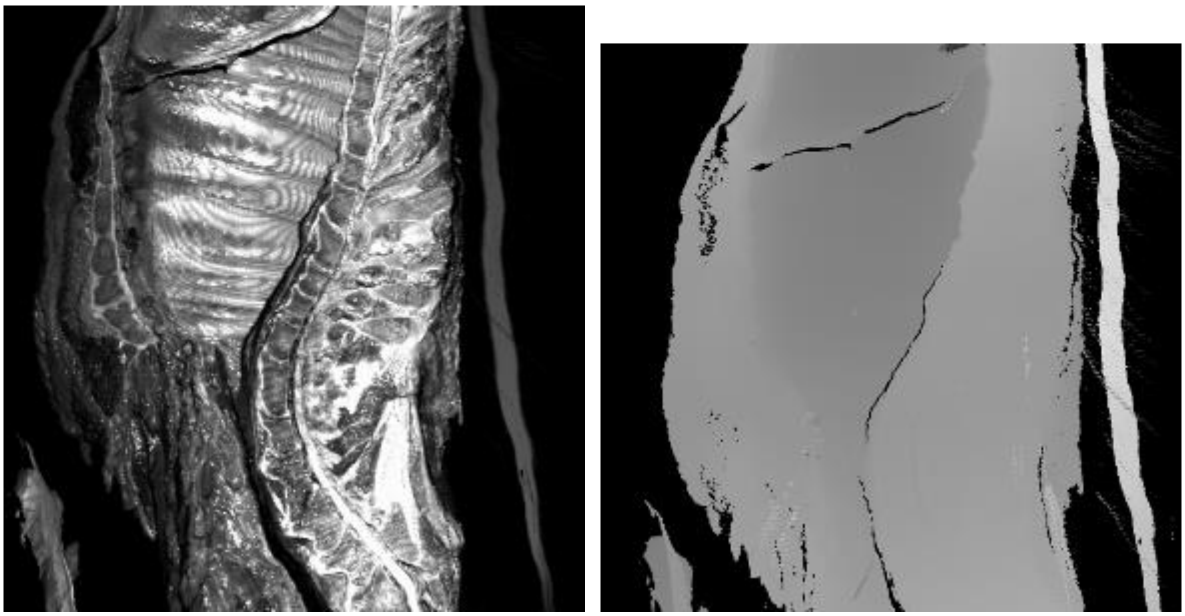

Fig.10 Image taken with Spinal Cord in place

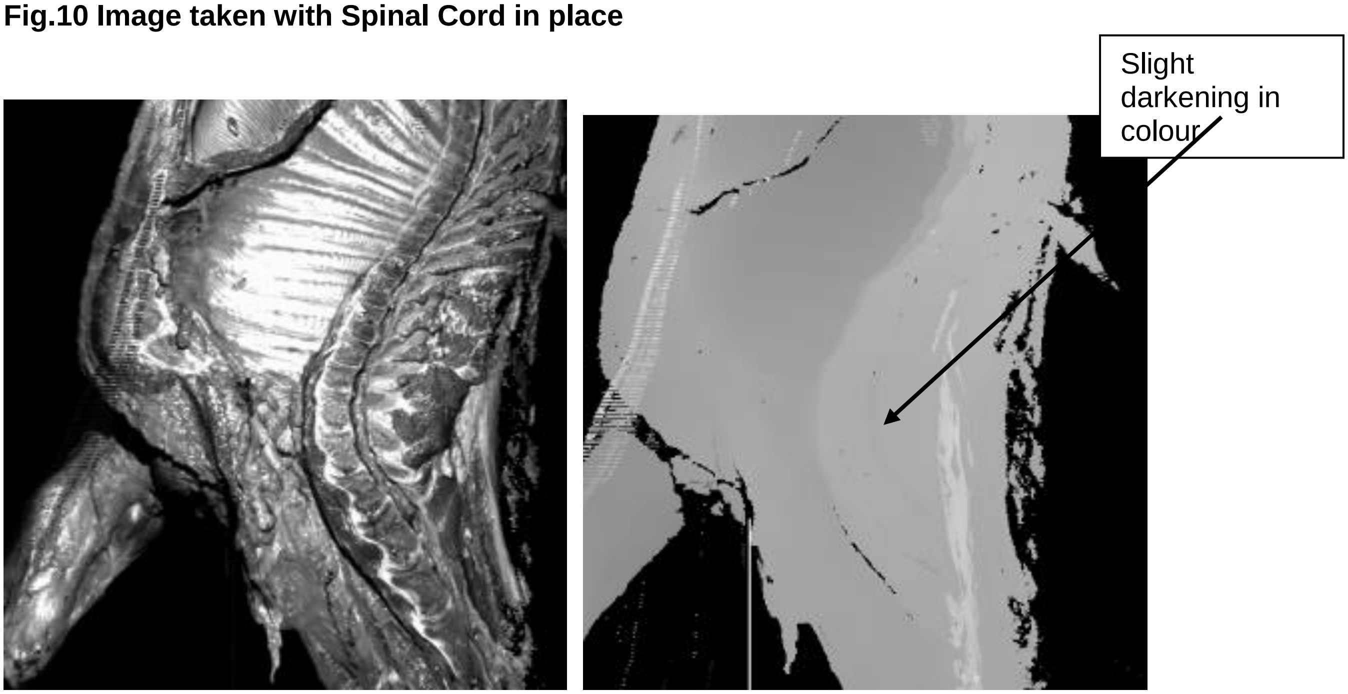

Fig.11 Image taken with Spinal Cord removed from the canal

In Fig.10 above the image is taken with the cord still in the canal, while the image in Fig. 11 is taken with the actual cord removed. Looking closely at the right hand image in Fig. 1 it can be seen that there is a slight darkening in colour in the area of the spinal canal that does not appear in the right hand image of Fig.10. Although this colour change is difficult to detect by eye it is 'visible' to commonly used vision software and the canal could be located. The obvious issue is that in most cases the cord will still be in the canal making detection of the canal itself difficult.

Further 3D trials were conducted as part of a concurrently running project, P.PSH.0619 Beef 3D camera sensing trials, using a Kinect 3D camera. As can be seen again, from the image shown in Fig.13 below, there is no detectable change in the colour of the 3D image at would allow the spinal cord canal to be detected. An alternative that is proposed here is that is would be possible to use the edge of the vertebrae as a guide and then use an offset from this to locate the spinal cord canal. This would obviously involve using a large number of images of beef sides to develop algorithms capable of determining this offset based on the size of the carcass and the 3D information received. An example of the results is shown below.

Fig.12 Colour Image of carcasses

Fig. 13 3D image received from the Kinect camera

In this image the carcass under inspection is shown as red as it is relatively close whilst carcasses in green are located behind. The variation's in the intensity of the red colour in this image shows the variation in depth across the carcass.

Below is an image that has been produced by processing the Kinect Camera data with Halcon software to remove the objects in the background. The Halcon software was then used to locate the edge of the vertebrae, this was found relatively easily and as can be seen from the values on the image below, a step change in the depth at the line of the vertebrae can be determined.

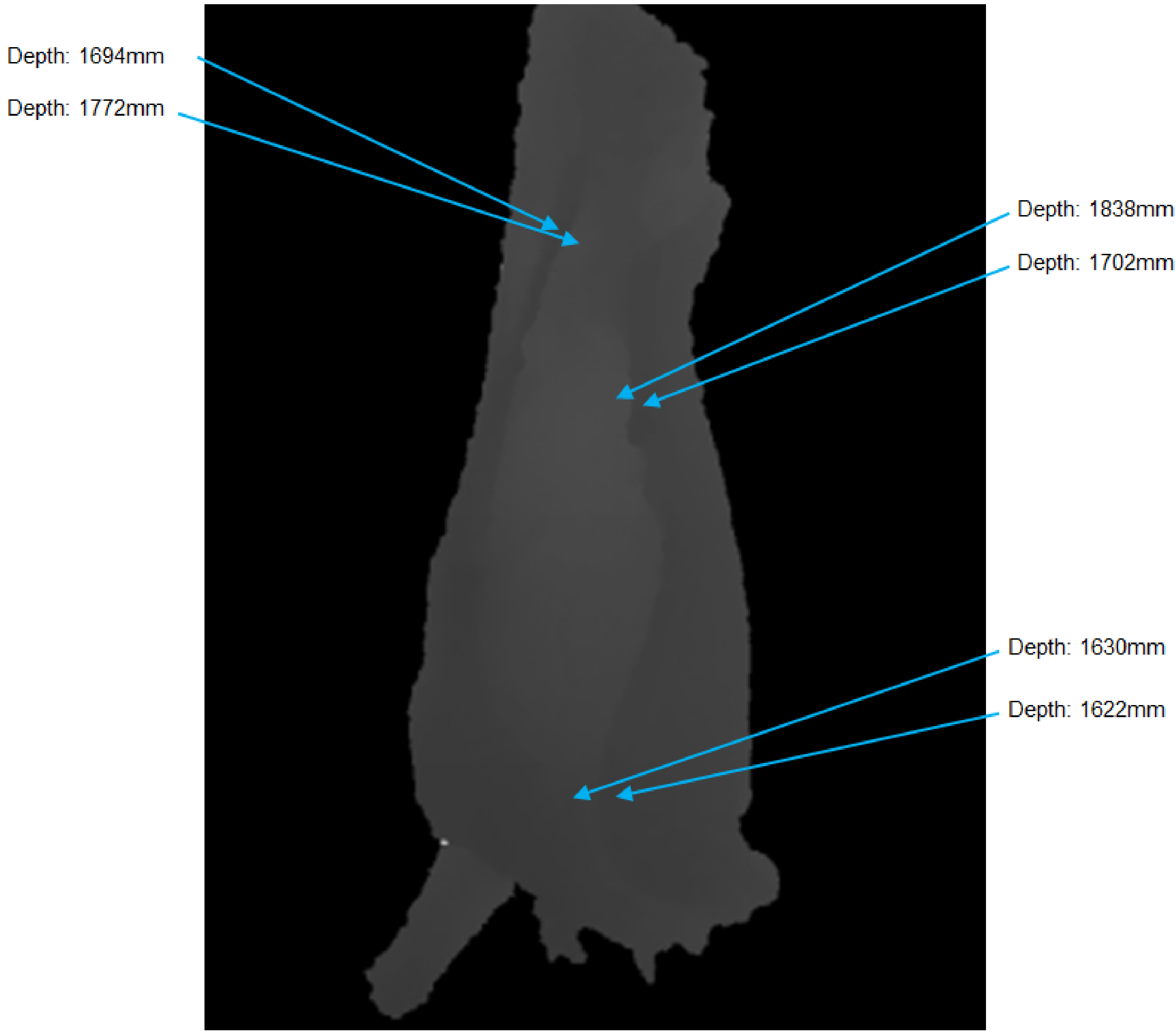

Fig. 14 3D image processed by the Halcon software, with depth data shown

4.3 Tool Concerns and alternate methods of removal

At this point concerns were raised within MAR with regards to the mounting of the tool onto the roll face of a robot. When using the tool manually the operator can manipulate the tool down the canal avoiding any broken backs/ protruding bones that may damage the tool. The concern is that when mounted to a robot the tool will travel along the path instructed with no account for any irregularities potentially damaging the tool. Additionally, following the results achieved from the vision trials, concerns were raised with regards to the accuracy required to locate the tool in the canal for it to adequately remove the spinal cord and duramata material. With this in mind thinking moved to how the cord could be removed with less accurate positioning of the removal tool, hence opening the door to possible detection of the vertebrae and offsetting to position in the vicinity of the canal.

As a trial MAR purchased a high flow/hi vacuum pump and tested simply vacuuming the cord away using a 40mm diameter hose. It was hoped at best the simple vacuum would be able to pull all the required material out without the need for a cutting tool and at worst remove the cord so an image could be taken. The results showed that the vacuum did remove the cord but left the behind the duramata which is also required to be removed. Initial thoughts with the cord being sucked away were that an image could then be taken with a camera and a cutting tool would follow the camera to remove the rest of the required material. Further internal discussion on this matter however decided that the idea of putting vacuum, a camera and a cutting tool on the end of a robot was not practical.

The idea of cutting away the duramata with high pressure water was raised at this point and discussed with several processors. The response from the processors was that it may work and be practical so long as water consumption was limited. The thinking is that the process may consist of a high pressure water spray as well as high flow vacuum to suck away the cord, duramata once it has been released and the excess water. Trials were conducted on site at Hardwick's Meatworks with promising results, with the high pressure water successfully removing all of the cord and meninges from the carcasses trialled. Points that required further attention were:

- Removal of the water and spinal cord and meninges material from the carcass once removed from the spinal cord canal.

- Determination of the minimum pressure and flow of water required to successfully remove all of the spinal cord and duramata.

With these points in mind MAR designed a hand held tool that incorporated a high pressure water nozzle and a high flow vacuum tube. The idea being that the vacuum would transport away the removed spinal cord, duramata and water as well as help stabilize the carcass.
Regulation of both the flow and pressure of the water was incorporated into the design so that these could be tuned during the trials. The position of the water nozzle was also made flexible such that its position with respect to the carcass could be adjusted to achieve the best results.
Trials with this tool were conducted at GM Scott Cootamundra and achieved mixed results. From a positive point of view the tool successfully removed the spinal cord and duramata from the spinal cord canal and it was found that a water pressure of 2000 psi achieved the best results. On the down side there were issues with containment of the High Pressure water and with carcass stabilization.

Following these positive results a phone discussion was held between AMPC, MLA and MAR. The conversation discussed possible concerns with regards to Food Safety, Market Access and Shelf Life of the product. It was acknowledged that:

- visual absence of spinal cord/duramata would be the key to the acceptance of any new process.
- recent trials had shown that the use of high pressure water left the carcase looking cleaner than current practices.
- containment and segregation from edible product of the water jet and removed spinal cord /duramata would be a key food safety concern.
- Negative impacts on shelf life are likely to be negligible given that the carcasses are already exposed to water from other processes particularly where spray chilling is applied
- The use of water in removal of bone dust may in fact have a positive effect on product presentation/shelf life.

As a result of this phone conversation it is proposed that a two pronged approach be used to allow investigation into multiple options for the removal of spinal cord.

3) In line with the positive feedback on the process of removing spinal cord and meninges with high pressure water, further develop the current high pressure water/ high vacuum tool. Further design would focus on developing a method of containing the spray so that ultimately all the spinal cord, meninges and high pressure water are vacuumed away.

4) In parallel with the above develop a tool that uses the cutting tool that is currently commonly used manually (shown below) and uses vacuum as a method of carcass stabilization.

MAR identified risks with both paths and have in the past indicated that automation with the manual cutting tool would be difficult. However the feeling was that that development of tooling to incorporate the manual cutting tool and conducting trials with this while on site trialling the High Pressure Water tool would be beneficial in identifying the potential of either method.

4.4 Manual Tool trials

A High Pressure Water Tool and tool incorporating the FPE cutting tool were both fabricated and trials with these tools at GM Scott in Cootamundra. The images below show the setup for both the HP tool and converted FPE cutting tool.

Fig.15 Equipment setup for HP water tool, the HP water unit and vacuum system are shown.

Fig.16 Equipment setup for converted manual cutting tool, the connection to the air supply and vacuum unit are shown.

The videos attached as well as the before and after shots shown in the photos below show that this method has good potential. The spinal cord and duramatta were successfully removed from the spinal cord canal and along with the water successfully vacuumed away from the area. The videos do show some water escaping from the tool but this was mainly due to the awkwardness in handling the tool and the force required to hold the tool firmly against the body against the force of the HP water. This would be overcome when the tool was mounted on a robot.

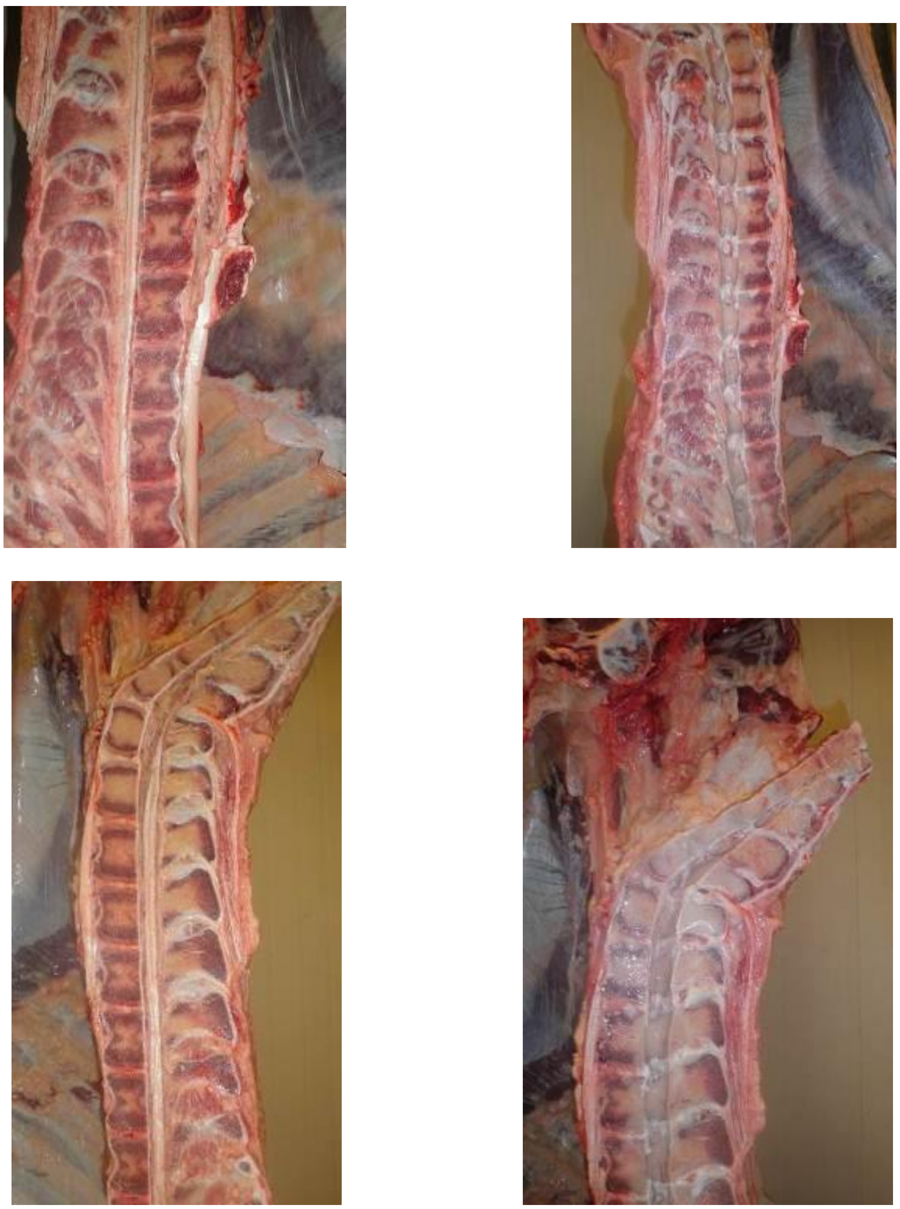

Fig. 17 The images above show the before shot on the left and the after shot on the right on two separate carcasses

The images below show some damage caused by the HP water on two separate carcasses. This was caused by the tool deviating from the ideal line of the spinal cord canal resulting from the difficulty in handling the tool due to the HP water. This could be overcome when using a vision/robotic system where the robot would have greater control over the path of the tool.

Fig. 18 Damage caused to carcasses

Trials with the FPE cutting tool followed, videos 3 and 4 attached to this report show these trials. The image below shows the tool being used during the trial. As can be seen from the videos our setup with the FPE tool in a chamber was unsuccessful in effectively removing any spinal cord or meninges. This was due to a couple of issues:

- There was insufficient vacuum flowing through the tool head (the supplied vacuum is split at the chamber between the tool itself and the pipework attempting to 'suck' the carcass to the tool). The lack of vacuum at the head of the tool meant that the cord was not sucked away from the canal and hence this did not allow the cutter to cut the cord and remove it from the canal.
- The head of the tool needed to be proud of the face of the chamber to allow it to access to canal. The angle of the tool in the chamber and the amount of tool that was proud of the face of the chamber made it difficult to position the tool in the canal and have the face of the

chamber hard up against the carcass meaning there was no vacuum crated between the carcass and the chamber.

Redesign of this tool and further trials would be required if we were to pursue this tooling path.

As a side note the tool was removed from the chamber and trialled by hand. It was found to work very effectively with the correct vacuum and the ability to manually manipulate the tool down the spinal canal.

Fig. 19 The adapted FPE cutting tool being used in trials

4.5 Robotic Tool Trials

Following the success of manual trials using the High Pressure (HP) water and vacuum tool, this tool was adapted to make it suitable for mounting on a robot roll face. Robotic trails were conducted with the kind assistance of staff at GM Scott Cootamundra. A backing board was used to support the carcass sides during the robotic trials.

The trials conducted involved positioning a carcass in front of the backing board teaching the robot/tool the path to be followed, dry cycling the programmed path and then running the robot through the cycle with water and vacuum running. The image below shows the MAR Project Engineer teaching the robot.

Fig.20 MAR Project Engineer Programming the robot

A total of 4 carcasses were trialled, and the results of these trials are detailed in the attached spread sheet and can be seen in the videos submitted with this report (burnt to CD and sent to Darryl Heidke).

It can be seen from the description in the spread sheet and the videos, that good results were achieved down the middle part of the carcass. In this region all the spinal cord and durra matta were removed when the spray nozzle was relatively well centred on the spinal cord canal. The neck and tail areas provided more of a challenge.

In the tail area, on the carcasses trialled, the opening to the canal was narrow making it difficult for the spray to access the cord and also for the cord to exit the canal. As discussed in the videos this could potentially be improved with more accurate location of the centre of the spray. This was difficult to achieve with the trial set up as it was hard to determine the precise centre of the spray with the tool itself in the way. In addition a slower pass of the robot over this more difficult to reach area would improve the results.

In the neck area of all four carcasses trialled, soft siding had occurred during the splitting of the carcass. This resulted in some bone covering the canal in this area making it difficult to successfully remove the spinal cord.

The video of the removal of the cord from Carcass 4 shows the issues that will be experienced if the water jet is not relatively well centred on the canal. It can be seen in this video that the jet was off centre by approximately 10mm and that this achieved a poor result in removing the cord and duramatta in all areas of the canal.

4.6 Concept Design

4.6.1 Concept Cell Design

Following manual and robotic trial work at GM Scott a concept design was developed back at MAR offices for a robotic spinal cord removal system both on a continually moving line and an indexed line.

The images below show both of these concepts. From the trials it was evident that the carcass side would need to be supported in some way during the removal operation. For the continually moving line it is envisaged that the carcass supporting equipment would be rotating bars that rotated 180 degrees between carcass sides and were sterilised while not in contact with a side. Alternatively the supporting equipment could be a continuously rotating conveyor that was sterilised while not in contact with a carcass side.

For the indexing line it is envisaged that the carcass supporting equipment would advance to support the side during the Spinal Cord Removal process and retract out of the way to allow indexing out of the processed side and indexing in of a new side. While this indexing was taking place the supporting equipment would be sterilised.

It is envisaged that the cell size would be similar to current MAR Robotic Brisket Cutting Systems.

The sensing system, as shown would be at the entry to the cell and the carcass side would be scanned on its way into the cell. The robot would then use conveyor tracking (which is currently used on all Brisket Cutting, Sani Vac and Kidney Fat Removal Systems) to track the carcass side and use the data from the sensing system to locate the spinal cord and remove it.

The tool sterilisation system would be mounted on the cell safety guarding posts and the tool would enter from the side, in a similar fashion to existing MAR Brisket Cutting Robots, between carcasses to be sanitised.

The robot controller and electrical control cabinet would need to be mounted in clean dry environment such as a control room or roof space while a suitably rated Operator Control Panel would be mounted to the outside of the cell. The system would need to be supplied with high pressure water (to the tool), factory pressure water (to the sterilisation system) and a vacuum system similar to those currently used on MAR's Kidney Fat removal Systems.

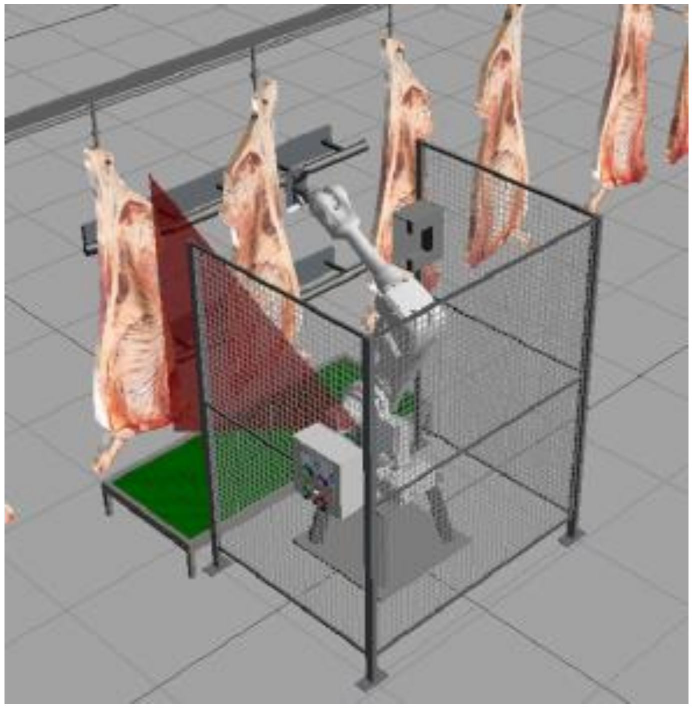

Fig.21 Continually moving line system, shown with bars that would rotate for sterilization between carcasses.

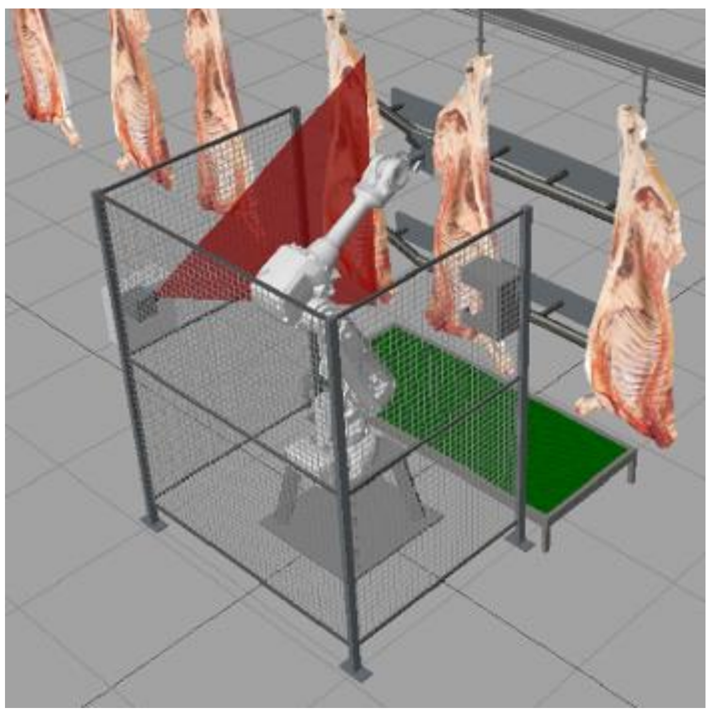

Fig.22 Continually moving line system, shown with bars that would rotate for sterilization between carcasses.

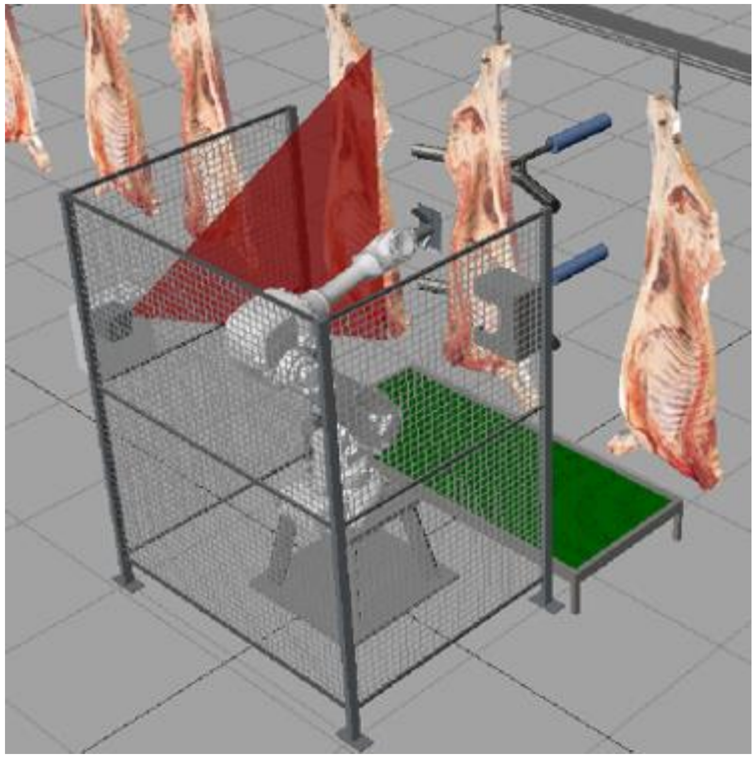

Fig.23 Indexed system, shown with supports that would retract to allow carcasses to index.

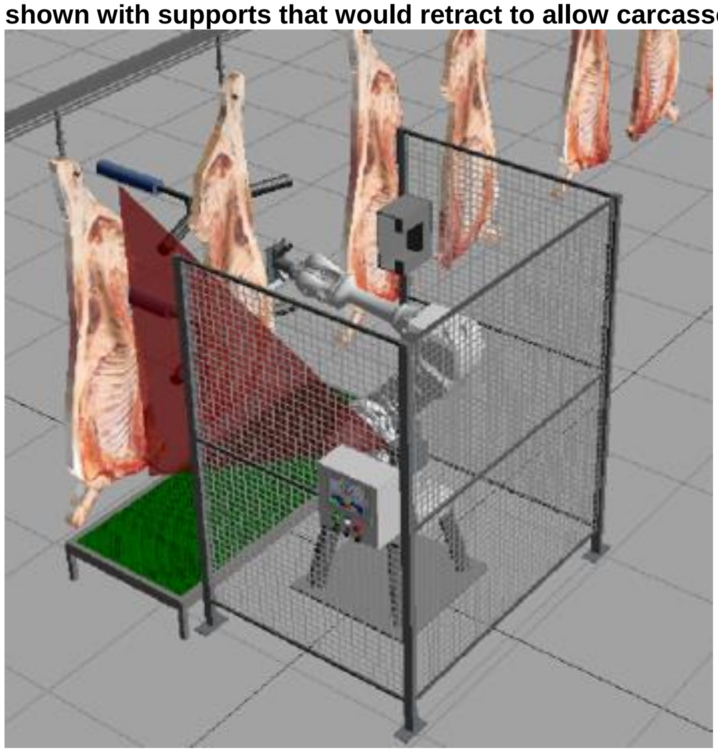

Fig.24 Indexed system, shown with supports that would retract to allow carcasses to index.

4.6.2 Prototype Tool Design

The initial concept tool that was fabricated resulted in a lot of water spray escaping from the tool as it simply had nowhere to go. The tool was redesigned to include a ‘chamber’ to give the vacuum a chance to suck the water away. The design above also had the water spraying from the bottom of the tool which resulted in excess spray spraying the ceiling and surrounding walls. Subsequent designs shown below had the water spraying from the top of the tool which resulted in any excess spray being directed onto the floor.

5 Success in Achieving Objectives

Through the investigative, design and trial work above the objectives of the project have been achieved and conclusions/recommendations are discussed in Section 7 of this report. Specifically the following objectives have been achieved:

- Current manual spinal cord removal methods were investigate and the most suitable and effective tool selected for robotic adaption and trials.
- Adaption tooling was designed and fabricated to allow manual testing of both the selected cutting tool and a combined high pressure water and vacuum tool.
- 3D sensing trials were carried out and options for use of 3D sensing in detection of the Spinal Canal were proposed
- Both Manual and robotic trials were carried out on the adapted tooling
- Concept designs for an automated and tooling were proposed.

6 Impact on Meat and Livestock Industry – now & in five years

An Automated Spinal Cord Removal System has the potential to impact the industry in the following ways:

- It will address the issue of shortage of skilled labour by removing the need for 1 – 2 labour units
- It will eliminate OH&S risks associated with manual task
- It will improve hygiene and shelf life by reducing manual handling of the carcass
- Reduced contamination

As discussed in the following section further work is needed in the areas of development of algorithms using the data from the 3D images to ensure accuracy in tool placement and tool compliance to overcome issues with water and spinal cord material being sprayed over other parts of the carcass.

7 Conclusions and Recommendations

Following the completion of the robotic trials, videos of the trials (which are on a DVD that have been forwarded to Darryl Heidke from MLA) were forwarded to industry expert, John Hughes, and Graham Treffone from JBS for comment, below are their responses:

John Hughes

"I have had a look at the video footage you sent, I am very interested and impressed at what I could see on the video, I would not be able to give a comprehensive and absolute acceptance without seeing the process in the flesh but I think you are on the right track to achieve an automated spinal cord removal system.
I have some concerns and that is :

- *splash onto the other areas of the carcass that would contaminate it with spinal cord material,*
- *that the high pressure of the water being forced into the meat through the nerve canals that service the length of the carcass*
- *the ability to present the side of beef in the correct position every time*
- *the ability to work with one robot at a chain speed that would warrant the expense of such a system.*

I hope that my comments are helpful and relevant, it is difficult to be confident in an opinion that is formed only after seeing a video."

Graham Treffone

"In regards to the footage I saw of the spinal vac robot, I have the following comments to add.

1. *The speed of operation would need to be much faster.*
2. *Although in most cases the spinal cord was removed, the duramata (spinal cord sheath) was not.*
3. *Care would need to be taken to ensure that SRM was not re-distributed to other parts of the carcase.*
4. *SOP would need to be put in place to ensure that any missed SRM was removed further down the process."*

In light of these responses and the videos of the trials it can be seen that there is potential for the use of a High Pressure Water and Vacuum Spinal Cord Removal Tool. It is evident, however, that there are areas that would require further refinement for the tool to be acceptable for use in the processing environment. These are:

- Confirmation of the ability of algorithms to be produced to enable the spinal cord canal to be located accurately enough for the HP Water tool to removal all the Spinal Cord and duramatta.

- Modifications to the tooling, possibly with the addition of some compliance, to allow the face of the tool to maintain contact with the carcass down the whole length of the side. This would reduce the likelihood of water/spinal cord/duramatta being splashed over other parts of the carcass,

- Concerns with regards to the water being forced into the meat through the nerve canals would require further investigation. This was raised during some of the trials at GM Scott, the carcasses were tracked through the system following removal of the cord and duramatta and no negative feedback was received.

- Cycle time and carcass stabilisation would also need to be addressed. MAR feel comfortable in achieving the goals required here particularly with the experience being gained with current projects such as rib cutting.

- Refinement of the required water pressure, flow and spray angle from the nozzle to achieve optimum results.

Hence it can be seen from the above results that the use of a High Pressure Water and Vacuum Tool for the removal of Spinal Cord from Beef Carcasses has potential and the work performed in this project has proven that the concept can be effective. The comments above show that there that there are some concerns from those in the industry, however MAR believe that these concerns can be addressed with further work and would recommend moving onto Stage 2 as outlined in the Background section of this document, that of a PIP project.