final report

Project code: P.PSH.0277

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Date submitted: April 2009

PUBLISHED BY
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Robotic beef splitting - cutting trials

This is an MLA Donor Company funded project.

Meat & Livestock Australia and the MLA Donor Company acknowledge the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Abstract

This project to perform cutting trials for beef splitting was initiated as part of MLA's plan to increase Meat industry's workplace safety which helps reduce OH&S claims that cost the industry hundreds of thousands of dollars annually.
Currently the beef splitting operation is performed manually by operators, using industrial band saws which are dangerous tools offering significant OH&S risks. The task is arduous to all operators and due to the requirement of accuracy to maximise yield cannot be performed by an unskilled person.
In conjunction with MLA, Machinery Automation & Robotics (MAR) funded 50/50 this project to conduct robotic beef splitting, cutting trials utilising a circular saw. The intention of the trials was to prove the capabilities of this setup to perform the beef splitting process together with evaluating the idea of a Robotic Beef splitting system that is primarily mechanically guided utilising minimal sensing technologies and hence minimising cost and complexity of a commercial system upon development completion.
The intention of the trials to prove capabilities has proven successful to the point that the next stage in this development should be commenced.
MAR will now seek interest from MLA and industry process partners to develop, manufacture, supply, install and commission a fully functional robotic beef splitting system. The intention would be to have a fully functional automated beef splitting system developed and installed by MAR which is in production within 12-18 months.
The potential benefits achievable by automating the beef splitting process include improvements in OH&S, product consistency, improved yield, and reduced labour cost.

Executive summary

Currently the beef splitting operation is performed manually by operators, using industrial band saws which are dangerous tools with significant OH&S risks due to the physical nature of the task. The mere use of such tools represent an OH&S problems due to the physical effort required to operate, even with aids like hanging cables and springs and there is potential for serious operator injuries.
This task is arduous to all operators and due to the requirement of accuracy to maximise yield can not be performed by an unskilled person.

The aim of the trials where to determine the capabilities of using a circular saw mounted on a robot system to perform the beef split process, and determine;

- If a suitable cost effective robotic solution could replace the current manual beef splitting process.
- If a suitable split/cut could be obtained using mechanical guidance and minimal sensing equipment.
- If robotically circular saw proved to be a suitable replacement to the band saw.
- What carcass stabilisation and control device would be required for a fully automated system
- If beef bodies of different breeds and with broken or bent spines could be cut successfully.

MAR initially commenced the Beef Splitting Trials using existing robot equipment on site at Northern Co-op, NSW. Trials at NCMC where unable to continue based upon the availability of suitable carcass variations and a suitable test location, however we where able to produce a number of semi successful carcass splits with some smaller bodies enabling some insight to the road ahead.

After some delay in seeking out a suitable second test site to continue trials, EC Throsby's in Whittingham, NSW offered their facilities to MAR for the purpose of continuing the trials which where conducted on site at ECT from December 2008 to March 2009.

A number of stabilisation mechanisms, various saw configurations and guidance systems along with the robot installation and services where installed, reconfigured and tested both at MAR and on-site at ECT throughout this period to conduct a series of controlled beef split trials with a focus on blade and robot guidance from both the rear (conventional way) and from the inside of the body.

A variety of beef carcass breeds ranging in size and condition where processed to cover a practical wide a range of test material.

Initial trials proved to be very promising with a number of successful splits though as different shaped beef bodies where introduced trials proved to be very challenging with a number of unsuccessful splits being completed leading to re-design and modifications to the test equipment throughout the trial process.

When splitting primarily with mechanical guidance from inside the carcass using the spine as a guide, a sufficient number of successful splits and saw guidance trials where achieved during the process to provide enough confidence that with a specially designed saw that has integrated guidance mechanism to track spine from both the inside and outside of the body will enable a fully

functional production ready system to be developed for the industry that meets production requirements and is relatively simple in design complexity.

The intention of the trials to prove the capabilities of using a circular saw mounted on a robot system to perform the beef split process has proven successful to the point that the next stage in this development should be commenced.

MAR will now seek interest from MLA and industry process partners to develop, manufacture, supply, install and commission a fully functional robotic beef splitting system. This development will require a staged approach with the first step being the development of a new saw with integrated guidance.

The intention would be to have a fully functional automated beef splitting system developed and installed by MAR which is in production within 12-18 months.

The flexibility of a robot controlled beef splitting system with integrated cutting and guidance fitted to the robot arm minimising additional sensing and hardware components in a production capable system will provide minimal footprint, complexity and cost with the flexibility to be used on fast continuous process lines or slower index processing lines.

Contents

1 Background

1.1 Industry Consultation

The project is a continuation of a MLA industry funded project in which industry consultation is required. MLA has presented to industry R&D dollars and through this process MLA and MAR have actively consulted the industry and concluded that this project will benefit the industry in terms of providing a path for automating the Beef Splitting process.

This Beef Splitting process as noted by processors within the Australian red meat industry would provide substantial benefit in automating. Consultation between the industry and MLA has shown that an Automated Beef Splitting process is an opportunity that should be moved forward.

The project has been developed as apart of MLA's plan to increase the Meat industry's workplace safety which helps reduce OH&S claims that cost the industry hundreds of thousands of dollars annually.

1.2 How did the project "come about"?

The industry has a valid need to have this process automated.

With experience obtained from other MAR conducted industry funded robotic processing projects currently underway or completed and with the knowledge to design and access available cutting tools suitable for conducting a Robotic Beef Splitting process, the obvious way forward was to first trial a standard off the shelf available circular saw, mount it to a robot system and determine the suitability of this setup for future development of a fully functional system by conducting a series of controlled splitting trials.

1.3 What currently happens and why does it need changing?

Currently the beef splitting process involves a skilled slaughterman manually operating an industrial band saw which is a dangerous tool with significant OH&S risk due to the physical nature of the task and the requirement to perform the task accurately.

Automation of the Beef Splitting Task would;
- Address shortage of skilled labour
- Eliminate dangerous operational practices
- Improve downstream processing
- Increasing productivity
- Improve yield

1.4 What alternatives have been investigated or are available?

Food Science Australia Have conducted trials for beef splitting using a band saw blade mounted on a robot arm to perform the splitting task however this system proved unsuccessful and has never been put into production:


Images from FSA Trials

Some European operators use automated beef splitting saws fitted with circular saw blades; however these systems do not provide the flexibility required for Australian beef processing due to line speed and cattle variations, they are also mechanically complex and inaccurate with soft siding being a common occurrence.

The current alternative to an automated system is the manual operated bandsaw.

1.5 What happens in other industries?

The Pork industry (primarily in Europe) are using robotic controlled splitting systems with circular saw blades similar in concept to that envisaged by MAR for the Robotic Beef Splitting system

1.6 Experimentation / Investigation work to date

Similar robotic technologies have and are currently being developed and installed by MAR throughout the Australian Red Meat Industry (Beef, Goat, Sheep & Lamb). Learning's achieved in these projects greatly assist and provide valuable input in the development of a Beef Splitting System.

Continued trials of new cutting tools and sensing technologies for use in the red meat industry also provide valuable contributions.

Food Science Australia Have conducted trials for beef splitting using a band saw blade mounted on a robot arm to perform the splitting task however this system was unsuccessful and has never been put into production: *(images above)*

1.7 Potential Benefits

Development of a fully functional automated Beef Splitting system would provide the following to the industry:

- Improvements in OH&S;
    - Elimination of risk of operator strain injury from the size, weight, and torque and risk of trauma injury from the cutting blade
    - Elimination of dangerous operational practices
- Consistency;
    - Robotic control of the saw will provide improved consistency of operations
- Improved yield through;

    - Improved cutting line accuracy
    - Less soft siding
- Labour availability & cost:
    - One automated splitting saw will replace 1-2 skilled slaughtermen labour units per shift.

2 Project objectives

The project objective was therefore to determine if a circular beef splitting saw can be integrated with robotics to provide an automated Beef Splitting solution suitable for the Australian Beef Industry and if so what future development is required to produce a working system solution suitable for production.

Within these objectives the following questions will be explored:

- Can a suitable cost effective robotic solution be developed to replace the current manual beef splitting process
- Will the circular saw with robot control provide a split/cut using mechanical guidance and minimal sensing equipment
- Will a robotically controlled circular saw provide a suitable replacement to the current band saw
- What carcass stabilisation and control device would be required for a fully automated system
- Can beef bodies of different breeds, broken or bent spines be split successfully

MAR have completed the following objectives as initially agreed within the project scope;

- Purchase and installation of the Beef Splitting Saw onto the existing Beef Scribing robot at NCMC.
- Test and prove the solution in controlled environment at NCMC as proof of concept will work in production environment
- Trial of the cutting tool and robot to achieve required client specifications
- The solution must also satisfy the speed and accuracy criteria's
- Document and video the trials for industry review

Based upon the limited tests and results achieved from the initial splitting trials completed at NCMC, MAR completed the following additional tasks adding to the original objectives agreed within the project scope;

- MAR made available an additional robot for purpose of trials at a 2nd site,
- Arrangements where made with ECT for MAR to install the splitting equipment and perform trials on-site
- New stabilisation systems where designed, manufactured and installed
- O/H rail systems where designed, manufactured and installed
- New saw guidance systems where designed, manufactured and installed
- Installation of the Beef Splitting System at ECT
- Further more extensive trials where completed at ECT by MAR to complete this project

3 Methodology

3.1 Project Progression

After initial setup and test of equipment at MAR Silverwater, Initial Beef Splitting Trials where completed in 2008 using existing robot equipment on site at Northern Co-op.

The trials at NCMC where unable to continue based upon availability of raw material and provision of a suitable test location.

MAR greatly appreciate and would like to thank NCMC for their assistance with this project

The trials conducted indicated initial success however further testing and equipment modifications where required to finalise objectives.

Based upon the above MAR sought a 2nd test site to complete the trials. Unfortunately this process delayed the project by a number of months until a suitable test site was located.

ECT, the second test site location was found. EC Throsby is situated in Whittingham, Hunter Valley of New South Wales kindly offered their facilities for use by MAR for the purpose of the trials.

E. C. Throsby Pty Ltd is a private, wholly Australian owned beef processing company established in 1991 that processes Bone In & Boneless Beef (Manufacturing & Primal Cuts), The plant which operates two 8 hour processing shifts over 5 days has the capacity to process approximately 460 animals per day.

Hardware and equipment to be used was initially setup by MAR at our Silverwater workshop to include a new robot, new stabilisation, guidance systems and modifications to the saw to ensure correct operation of the equipment prior to shipment to E C Throsby. Trials where conducted at E C Throsby from December 2008 to March 2009.

MAR received assistance from ECT throughout the process with maintenance and production staff being involved in the trials and sharing valuable process knowledge of beef splitting.

MAR greatly appreciate and would like to thank ECT for their patience and assistance with this project

3.2 System Setup 1st Site NCMC

Initial Beef Splitting Trials where completed in 2007/08 using existing beef scribing robot equipment on site at Northern Co-op.

Only small whole bodied carcasses where able to be positioned within the chiller which current houses the Robotic Beef Scribing MAR Development system.

The saw was mounted to the robot in its installed position with bodies positioned on adjacent O/H rails.

Images from MAR conducted Trials at NCMC

Reference to Videos:
 MAR-PPSH0277 CUT@NCMC Feb08.mpg

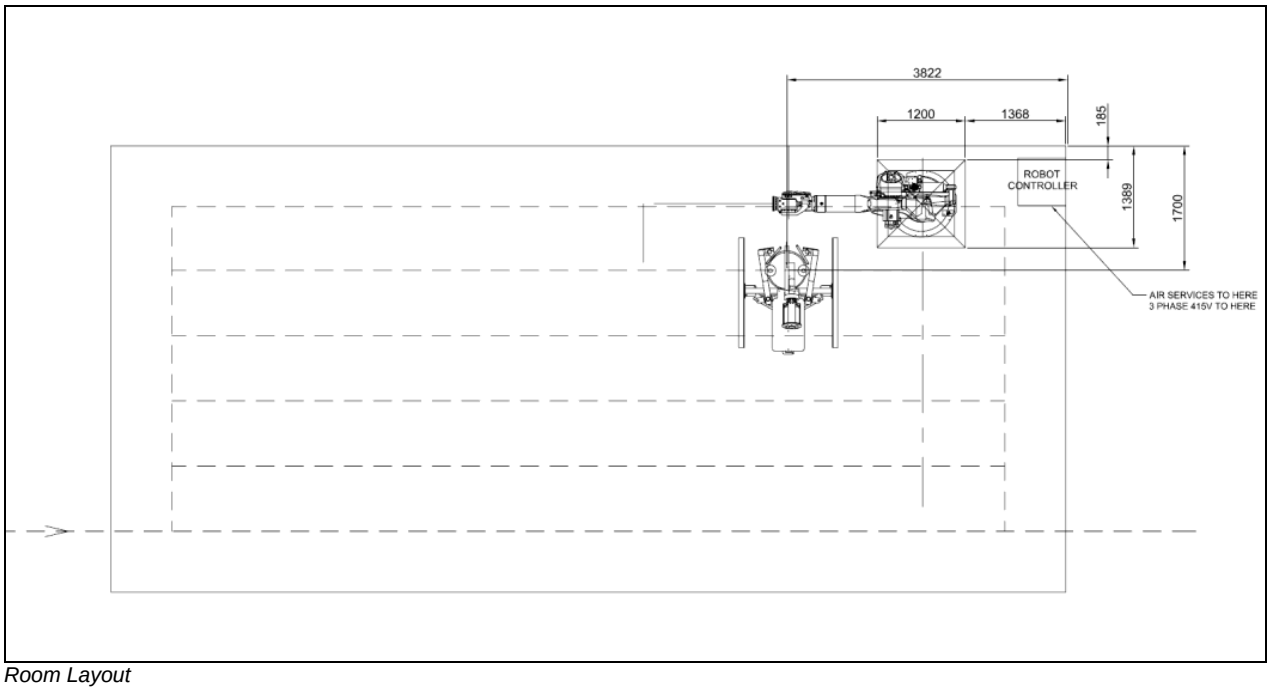
3.3 System Setup at MAR Silverwater

Hardware and equipment to be used was initially setup by MAR at our Silverwater workshop to include a new robot, new stabilisation, guidance systems and modifications to the saw to ensure correct operation of the equipment prior to shipment to E C Throsby.

Image of Equipment setup at MAR

3.4 System Setup 2nd Site ECT

The system installed by MAR at ECT was set up in the least used corner of a buffering chiller. This chiller is only fully utilised on occasions providing and ideal location to perform trials.

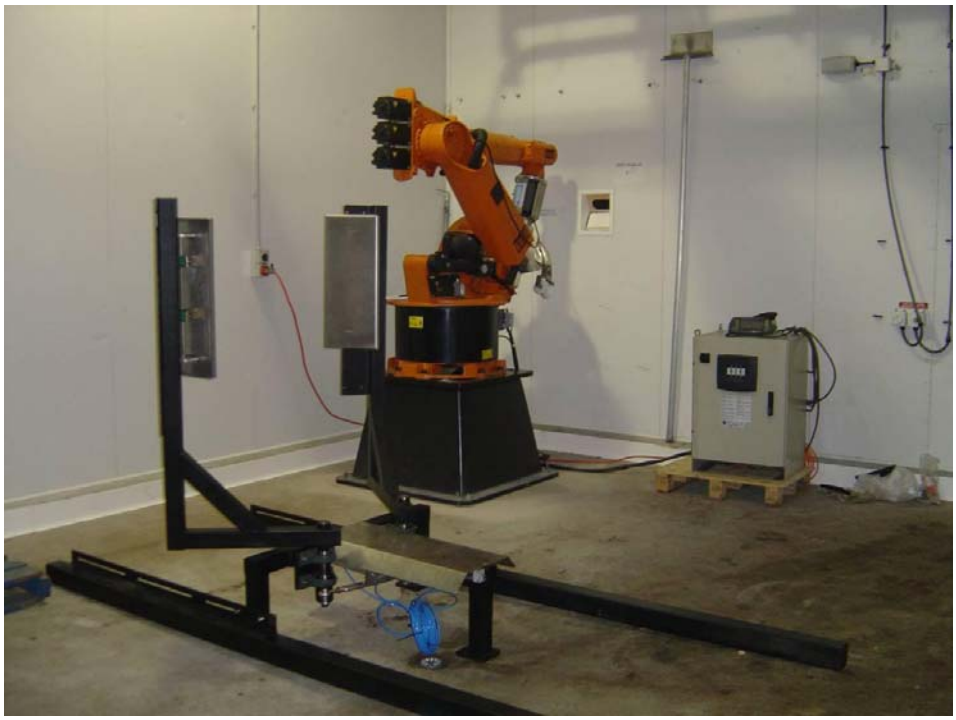


Room Layout

Image of ECT Chiller prior to install

Components for the test system included:

- Freund circular saw – to be used for cutting the spine during the trials and mounted to the robot manipulator
- Saw Guidance – Used to position body and guide robot/body through the splitting operation
- Kuka Robot manipulator – to move the saw and determine the cut path
- Kuka Robot controller – to control the robot manipulator and switching on / off of the saw
- Body stabiliser – for stabilising & holding the body when it is hanging from the overhead rail
- Leg spreader – used to spread the hind legs of the animal on the rails



Freund SK72
Splitting Saw Attached to Robot

Leg Spreader used for the trials

Leg Spreader in use

Body stabiliser used for the trials

E C Throsby kindly provided the following services to MAR to setup equipment for the trials:

- Fork lift truck & operator to aid in the unloading of the truck when the equipment arrived on site
- phase power outlet to power the robot
- Water supply used for the washing of the body whilst the cut is taking place
- Air supply required for the operation of the leg spreader and the body stabiliser
- Sanitiser used to sanitise the equipment at the start of the day
- Hot water supply for sterilisation of equipment after each cut
- Hair nets, gloves, overcoat, and additional cleaning equipment
- Manual handling, positioning and supply of all beef used for trials

3.5 Basic Test Procedures & Control Philosophy

The basic test procedure and control philosophy used for the trials is as follows:

1. Full body carcasses where manually brought into the chiller long production breaks or end of shift. This work was completed by ECT and required significant manual handling
2. The carcass body was positioned with leg spreader operated.
3. Carcass stabilisation was initiated to position carcass prior to cut
4. The robot moves into position.
5. The saw is started, but moves in slowly to allow the blade to reach full speed before cutting any bone.
6. The blade will first have to cut the small bone above the anus.
7. The guidance system is positioned and pushed around the spine just below the anus and pushes the carcass away from robot..
8. When the saw is mid way down, the body stabiliser is opened. This lets the brisket bone open up and takes pressure off it, allowing the saw to pass through easier.
9. Spine tracking is assisted with the robot and guidance mechanism applying pressure onto the carcass pushing the back bone.
10. The saw is moved all the way down the carcass at 80 - 150mm/s (optimal speed to be determined at a later date) until it comes out at the neck area.
11. The saw is retracted and then turned off as it moves back to the home position.

4 Results and discussion

4.1 General discussion

Trials completed initially at NCMC proved only that the robot controlled saw could cut small beef bodies with relative ease and that sufficient success was observed to continue the trials after modifications to the setup.
At ECT a series of dry cut and guidance trials where completed plus a total of 29 full body cuts/splits being performed. Of these cuts a total of 16 were from the inside of the body and 13 from the rear of the body. Beef bodies provided were from a variety of cows of different breeds and sizes. No bulls were attempted due to the difficulty of positioning within the test room and the man handling required to do so.
Numerous trials where conducted without the use of the splitting saw to setup and trial various configurations of the saw guidance system.

The above trials where completed to address and answer the following:

- Could the circular saw be used as a replacement to the band saw?
- Is the robot system and circular saw setup able to be used to split bodies with broken or bent spines and backs?
- Will the automated system maintain production rates?
- Is the robot saw and guidance system capable of producing sufficient carcass manipulation to perform straight split even with bent/broken spines?
- Is the body stabiliser necessary for the cutting process?
- Will both the body and neck area be cut accurately?
- What water rinsing/flushing is required to provide saw blade lubrication and minimise bone dust?
- Is any rinsing required for excess bone dust?
- Can a suitable cost effective robotic solution be developed to replace the current manual beef splitting process
- Will the circular saw with robot control provide a split/cut using mechanical guidance and minimal sensing equipment
- Will a robotically controlled circular saw provide a suitable replacement to the current band saw
- What carcass stabilisation and control device would be required for a fully automated system
- Can beef bodies of different breeds, broken or bent spines be split successfully

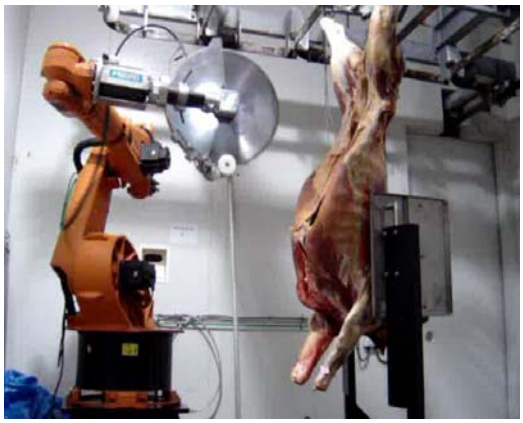
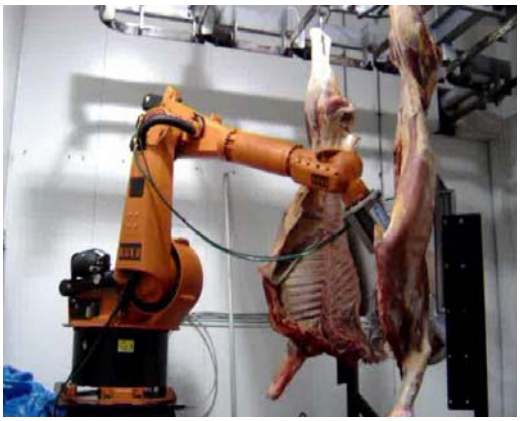
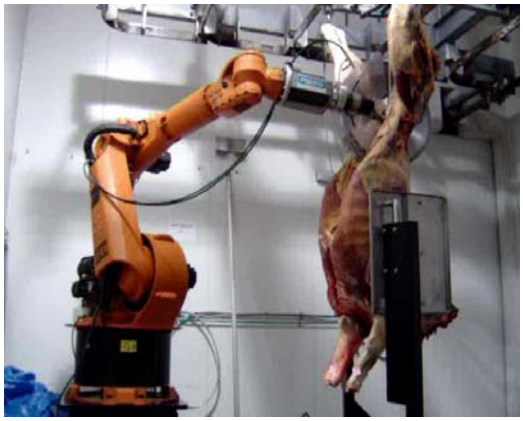
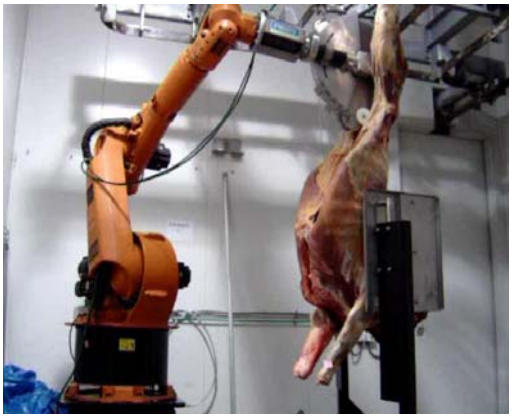
Details from the results of these trials follow;

4.2 Performing Beef Splitting with Internal Spine Guidance

From the total of 29 full body cuts/splits performed at ECT, 16 bodies where split guiding the carcass through the robot and the saw blade from the inside of each body using the spine.
Throughout these 16 splitting trials various software and hardware configuration and combinations where used, these included:

- Cutting Speeds from 30mm/sec – 200mm/sec
- Robot path and pressure applied to body
- Guide roller position in relation to saw
- Guide roller spacing and dimensions

- Water coolant for saw (off/on)
- Water coolant for saw and bone dust suppressions (various positions, pressure, flow and number of outlets)
- Body stabiliser operations (used, not used and operated at different times throughout cycle)
- Additional neck strap used

Setting up the system to cut from the inside of the carcass and by guiding body through the saw from the inside of the carcass was deemed to be the most probable solution to produce the best results based upon completion of initial trials conducted at NCMC, completion of dry cut guidance trials and knowledge of other beef splitting systems that have been tried and do not perform.

The following outlines some of the specific findings from this set of trials.
The circular saw was able to provide a good quality cut from the inside, with the exception of the neck. To obtain a quality cut on the neck further development of the guidance system will be required to locate and position during the splitting performance. This would produce similar results as seen when guiding the robot from the outside of the carcass.

At a slow cutting path speed though (less than 80mm/s), the saw did produce a significant amount of bone dust. The original washing system was modified to suit, which consisted of two spray jets at either end of the saw which washed the body from the inside and also form the rear of the body. This reduced the amount of bone dust remaining on the body after cutting. As the

cutting path speed was increased (up to 150mm/s), the amount of bone dust decreased. The combination led to minimal saw dust with an acceptable amount remaining on the body.
Cut speeds <80mm/sec minimised production speed capabilities and created excessive bone and saw dust.
Cut speeds >80mm/sec provided acceptable production speed capability together with minimal bone and saw dust.
Cut speeds >150mm/sec provided acceptable production speed capabilities however produced undesired instability in the body reducing cutting accuracy and performance.
Not all splits attempted produced a good cut however sufficient knowledge was gained during these failed attempts

Several guidance system design stages were used, finally leading to a self adjusting pre-tensioned guide. This guide was able to position the spine and keep it within the guides.
A further advantage of cutting from the inside is the cut path requires less movement around the anus area to compensate for different breed types, with differing shapes.

The body stabiliser proved not to be required during the cutting process. As the stabilisers “doors” made contact with the body, they closed the brisket area creating more of a situation for the robot to get caught on. They also did not aid in the straightening of a spine. The natural weight of the body in the guide was sufficient to keep the body in place. A revised version of the body stabiliser should be used during production to suppress any “swing” of the body prior to cutting.

4.3 Performing Beef Splitting with External Body & Spine Guidance

From the total of 29 full body cuts/splits performed at ECT, 13 bodies where split guiding the carcass through the robot and the saw blade from the outside of each body using the spine and natural curvature of the body.

Throughout these 13 splitting trials various software and hardware configuration and combinations where used, these included:

- Cutting Speeds from 80mm/sec – 150mm/sec
- Robot path and pressure applied to body
- Guide roller position in relation to saw
- Guide roller spacing and dimensions
- Use of guidance plate rather than rollers
- Water coolant for saw (off/on)
- Water coolant for saw and bone dust suppressions (various positions, pressure, flow and number of outlets)
- Body stabiliser operations (used, not used and operated at different times throughout cycle)

Setting up the system to cut from the outside the carcass was completed to determine some unknowns in relation guidance capability and to establish if a good neck cut can be achieved.

The following outlines some of the specific findings from this set of trials.

- The circular saw was able to provide a good quality cut from the rear, and this included the neck, but was very unreliable around the shoulder area were there is a large amount of fat, and the shape differed from breed to breed.
- Four revisions of the guidance system where used to obtain a reliable cut.
- Trials completed where unsuccessful, if the body was not positioned perpendicular or the natural spine was not straight.
- Each guidance mechanism used was unable to move straighten the spine due to movement in the meaty/fatty shoulder area.
-
- The saw did have no problems cutting through a broken back.
- The trials from the rear were all conducted at a cutting path speed of 80mm/s.
- Initially the saw did produce a significant amount of bone dust. The original washing system tap was modified to provide a third washing point. The bone dust would have also been reduced with an increased cutting speed as found when cutting form the inside.
- Trials proved that mechanical guidance of the carcass through the saw when cutting from the rear would prove very difficult when accommodating bodies of variant breeds and profiles in particular as the anus area, like the shoulder area has a wide variety of shape from breed to breed.
- Use of the body stabiliser proved inconclusive during this cutting process. The natural weight of the body in the pressure applied by the guide was sufficient to keep the body in place.

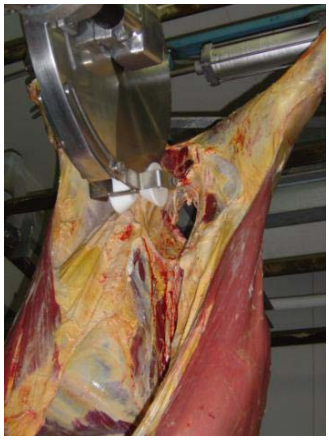
4.4 Performing Internal Spine Guidance Trials

Before during and after completion of the 29 full body cuts/splits performed at ECT a number guidance trials where completed without the saw being used. (Dry Cutting Trials)

One primary focus of these trials was to mechanically guide and position the carcass throughout the splitting cycle to ensure the robot and saw produce the best cut with no soft siding and to

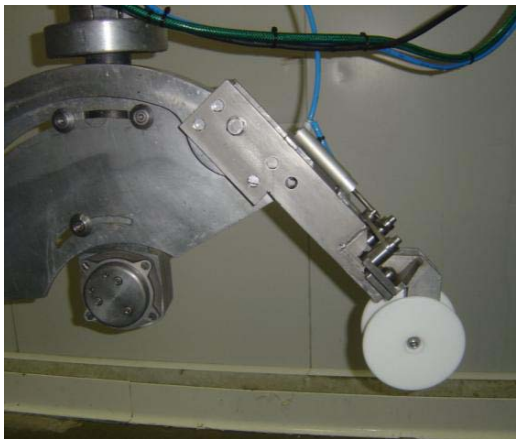
minimise the use of sensing and other technologies that would increase cost and complexity of a production capable system.

Several guidance system designs were tested finally leading to a self adjusting pre-tensioned guide. Some of these are shown below:



Rollers mounted to Saw

Formed Plate mounted to Saw



Pre-Tension roller mounted extended from saw

The self adjusting pre-tensioned guide used when cutting from the inside proved very successful being able to straighten the spine keeping it within the guides regardless of body position, straightness and spine/back condition.

Tests were carried out using bodies with straight spines and the robot programmed to offset the end of its cutting path by up to 50mm. the guide successfully managed to position each spine and keep it located between the guides. Similar tests where completed on bodies with bent and broken backs and these proved successful.
Along with the 29 completed beef splits these trials proved invaluable for future development of an automated beef splitting system. Future development will require further refinement to ensure the spine is kept central within the guide always. Most likely this will be achieved by changing the profile of the guide and increase compensation flexibility to deal with non symmetrical shaped spines and a larger range of body sizes.

One area that did not produce satisfactory results within these cutting trials when cutting from the inside of the body was the consistency in cutting the neck area of the body. This was realised early to be difficult to accomplish with the saw design in its current state. Trials completed cutting from the outside of the body proved more successful in cutting the neck and draft plans have been realised for a saw design that will combine both internal and outside guidance for the saw to provide ideal cutting and guidance condition for the robot guided beef splitting saw.

Upon completion in design for a new saw in the next stage of development, further guidance trials will be completed to prove guidance capabilities prior to any cutting tests being completed for confirmation.

5 Success in Achieving Objectives

5.1 Objectives for Robotic Beef Splitting - Cutting Trials

MAR has completed the following objectives as initially agreed within the project scope;
Purchase and installation of the Beef Splitting Saw onto the existing Beef Scribing robot at NCMC.

Test and prove the solution in controlled environment at NCMC as proof of concept will work in production environment
Trial of the cutting tool and robot to achieve required client specifications
The solution must also satisfy the speed and accuracy criteria's
Document and video the trials for industry review

Based upon the limited tests and results achieved from the initial splitting trials completed at NCMC, MAR completed the following additional tasks adding to the original objectives agreed within the project scope;
MAR made available an additional robot for purpose of trials at a 2nd site,
Arrangements where made with ECT for MAR to install the splitting equipment and perform trials on-site

New stabilisation systems where designed, manufactured and installed
O/H rail systems where designed, manufactured and installed
New saw guidance systems where designed, manufactured and installed
Installation of the Beef Splitting System at ECT
Further more extensive trials where completed at ECT by MAR to complete this project

6 Impact on industry

6.1 Impact of Beef Splitting Trials – now and in five years time

The intention of the trials to prove the capabilities of using a circular saw mounted on a robot system to perform the beef split process proved successful to the point that the next stage in this development should be commenced.

Although completion of these trials does not have an immediate and direct impact for the industry, the intention would be to have the first MAR fully functional automated beef splitting system developed, installed and in production within 12-18 months.

Development of a fully functional automated Beef Splitting system would provide the following to the industry:

Improvements in OH&S;

- Elimination of risk of operator strain injury from the size, weight, and torque and risk of trauma injury from the cutting blade
- Elimination of dangerous operational practices
- Consistency;
- Robotic control of the saw will provide improved consistency of operations
- Improved yield through;
- Improved cutting line accuracy
- Less soft siding
- Labour availability & cost:
- One automated splitting saw will replace 1-2 skilled slaughtermen labour units per shift.

Within five years a fully developed commercial available automated beef splitting system will be available with multiple installations 5-10 sites expected within this time.

7 Conclusions and recommendations

7.1 Conclusions

The aim of the trials where to determine the capabilities of using a circular saw mounted on a robot system to perform the beef split process, and determine;
If a suitable cost effective robotic solution could replace the current manual beef splitting process.
If a suitable split/cut could be obtained using mechanical guidance and minimal sensing equipment.
If robotically circular saw proved to be a suitable replacement to the band saw.
What carcass stabilisation and control device would be required for a fully automated system
If beef bodies of different breeds and with broken or bent spines could be cut successfully.

When splitting primarily with mechanical guidance from inside the carcass using the spine as a guide, a sufficient number of successful splits and saw guidance trials where achieved during the process to provide enough confidence that with a specially designed saw that has integrated

guidance mechanism to track spine from both the inside and outside of the body will enable a fully functional production ready system to be developed for the industry that meets production requirements and is relatively simple in design complexity.

Key reasons for the above conclusion are;

- Cost effective solution achievable due to;
  - No complex sensing was used and/or deemed required during tests
  - Body stabiliser is not required during splitting cycle; this will keep complexity and footprint at minimal levels.
- Obtaining suitable split by mechanically guiding saw from inside body;
  - Spine is accessible for guidance to straighten and centralise carcass for cut
  - Cut path of the saw requires less movement around the anus area providing faster cycles and reducing cell footprint
  - Excessive fat or external body features seen on some breeds do not influence guidance.
- Robotic guided saw capabilities;
  - Successful splits achieved proved to have good cut line accuracy with minimal bone dust and completed at acceptable rates.
  - Splitting/Cutting at production rates can be achieved
  - Minimal complexity allows for minimal footprint and provides capable design solutions that will fit within existing slaughter floors to replace current manual operations.
- Required stabilisation and control devices for a fully automated system;
  - Body stabiliser is not required during the cut cycle although a simpler device will be used to ensure body stability on indexing lines.
  - A new saw to be developed that will incorporate the existing internal spine guidance and external guidance to ensure successful neck cuts are achieved
  - Minimal and simplistic sensing equipment will be required to determine body size for start of cutting cycle.
  - Excessive bone dust can be overcome with a suitable flushing mounted to the robot.
- Success of splitting beef of different breeds and with broken or bent spines
  - Internal guidance, minimises variables allowing design capabilities for variant beef breeds, size and conditions.
  - Bodies with bent spines or bodies not hanging straight can be guided/straightened using the robot guidance mechanism.
  - Broken back spines can be located correctly and split.

7.2 Recommendations

MAR will now seek interest from MLA and industry process partners to develop, manufacture, supply, install and commission a fully functional robotic beef splitting system. This development will require a staged approach with the first step being the development of a new saw with integrated guidance.
The intention would be to have a fully functional automated beef splitting system developed and installed by MAR which is in production within 12-18 months.