final report

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Automated beef splitting – Stage 2

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Abstract

The objectives of this project were to investigate the ability to successfully split a Beef Carcase using a circular or bandsaw guided by a mechanical guidance system to ensure splitting of the carcase down the centre of the back bone.
The body of this report shows the development of a guidance mechanism firstly for a circular saw and then for a linear saw and discusses the trials that were conducted to prove its operation.

Executive Summary

Following and initial review of the potential saw available for splitting beef the circular saw was selected as the saw to be used in the trial for this project. An integrated guidance mechanism that tracks the spine from both inside and outside the carcase was developed and trial at EC Throsby in Singleton. Initial trials showed that the guidance mechanism successfully tracked the spine down the majority of the body until the neck region where the boss of the saw contacted the carcase and caused the body to skew and soft siding to occur. Guards were manufactured to cover the boss and also the other side of the saw blade with a view to making the cut even. Issues were experienced with these guards fitted where by the saw had difficulty travelling down the carcase due to the with across the saw due to the guards. Following several attempts to overcome this interference the decision was made to fit a similar guidance mechanism to a band saw to see if that gave better results. The results achieved from the bandsaw trials were similar to the circular saw before the guards were fitted, it tracked well down the majority of the carcase however soft sided in the neck area. Modifications to the saw and guidance setup are proposed in the Conclusion and recommendations section.
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1 Background

The Automated Beef Splitting project 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.

The Stage 1 of this project proved the capabilities of a robotically controlled circular saw 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.

Based on the completed Stage 1 trials, a concept that includes a specially designed saw with integrated guidance mechanism to track the spine from both the inside and outside of the body has been realised.

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.

1.1 Estimated system cost and cost benefits after development

The following outlines the estimated cost benefits and the impact to the Processor after development of an automated beef splitting system which would be the next stage after completion of these trials.

The cost benefit will be in terms of labour reduction, Yeild gain, reduce contamination and suppression of OH&S claims related with the task.

Plant labour cost never less than $65,000 per shift per year.

The cost benefit in terms of OH&S claims will be specific to each site and dependant upon the size and speed of the processing plant. Other operational cost benefits are outlined below;

Outline of cost Benefits based upon industry consultation;

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

It is estimated that the potential commercial cost for an Automated Beef Splitting system will be less than <$450K. With labour and OH&S savings plus yield gains achievable, implementation of an Automated Beef Splitting system will provide payback to processors within 2 years of installation.

2 Project Objectives

The purpose of these Stage 2 Beef Splitting trials are primarily focused on the development of a saw with integrated guidance and to test and trial this saw to ensure the concept will perform as required prior to exposing any individual processor to the risk of installing a system that has remaining unanswered design, operational and reliability questions.

Design, Operational & Reliability points to be addressed during project:

- Use of Circular Saw or Bandsaw
- Saw & Guidance system design
- Saw/Tool Life
- Operational Cycle Performance
- Potential Installation and Operational Costs

The project is based upon the integration and testing of the following main components;

- Splitting Robot Manipulator
- Splitting Tool (specially designed beef splitting saw with integrated carcase guidance)
- Whole Carcase stabilisation and Spreader
- Minimal sensing technologies
- Cell Control System

3 Methodology

The project is divided up into the following milestones and these formed the structure of the project.

Milestone 1 - Initial Design & Project R&D

- MAR will conduct and review with MLA a full project Risk assessment document that includes a detailed analysis covering technical, process, schedule, financial, resource, design and commercial risks including action plans to deal with each identified risk throughout the life of the project,
- Prepare draft design for new “Circular Blade” splitting saw, guidance and stabilisation equipment.
- Prepare draft design for new “Bandsaw” splitting saw, guidance and stabilisation equipment.
- Review pros and cons of the draft saw designs to establish best saw system to be used for trials.
- Initial Design R&D, includes potential designs for future sites and ensuring the design meets the requirements of potential future processors who will take on this technology.

Milestone 2 - Beef Splitting Saw Development

- Design for manufacture of new beef splitting saw, guidance and stabilisation equipment based on draft design review.
- Obtain & transport robot and saw components.

- Purchase components and manufacture of new saw setup
- Setup and install splitting saw at MAR

Milestone 3 – Trial System Components

- Purchasing of system components and delivery to MAR to begin system build integrating and programming.
- Robot Base Frames and accessories
- Control system interface and saw control components
- O/H rail spreader components

Milestone 4 - Beef Splitting Setup at MAR

- Setup and install robot and splitting saw
- Mechanical & Electrical Setup & Test of System
- Programming of robot & control system interfacing
- Test tooling robotic operated
- Perform dry run trials (no carcase)
- Videos, reports and documentation detailing results of trials

Milestone 5 – Site Preparation for on-site trials

- Prepare site (chiller space) for installation
- Preparation of Services (water, power, etc)

Milestone 6 - On-Site Installation of Trial Equipment

- Equipment Transport to Site
- Installation of robot system
- Installation of other system components
- Electrical and services installation

Milestone 7 – System Setup Testing & Trials

- Mechanical & Electrical Setup & Test of System
- Test tooling robotic operated
- Setup and test manual operations
- Setup and test guidance system (dry cycle operations)

Milestone 8 – Beef Splitting Trials

- Full carcase delivery trial location
- Perform a series of Beef Splitting Trials
- Cycle Time, Tool Life, Carcase Type Trials
- Document and video all trials

Milestone 9 - Presentation Video, Documentation

- System Videos, reports and documentation detailing the outcome of the trials, its components and operational procedure to be provided by MAR to MLA for industry dissemination and promotional purpose

Milestone 10 - Presentation & On-site Open Day

- Preparation, contact potential clients & arrangements
- Site Setup For Presentation

- Presentation to Industry by MAR with MLA
- Document and video all trials

4 Results and Discussion

4.1 Initial Design and Project R & D

Draft designs for both the circular saw and bandsaw incorporating mechanical guidance for both the inside and outside of the carcase were developed as shown in the images below.

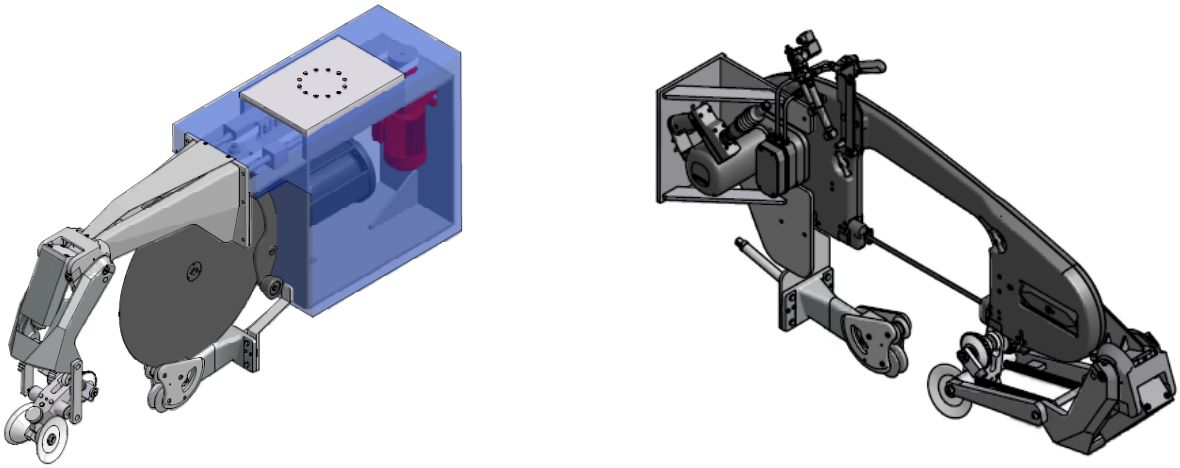


Fig.1 Concepts for Circular and Band Saw Guidance Mechanisms

The two concepts both had their advantages and disadvantages. As a method of comparison the table below was used to establish which of the two was the preferred option. The table discusses particular aspects of the splitting process and ranks each concept with a 1 if it is the preferred concept for that aspect and a zero if it is not. The rankings are then summed to determine the preferred concept to be used for trials. From the results in the table below the decision was made to pursue the circular saw option.

`	Circular Blade	Rank	Band Saw	Rank
Soft siding	Will maintain cut line without flexing.	1	More likely to stray off line if tough bone matter encountered.	0
Broken Back	Prior trials have proven that circular saw can maintain cut line when a broken back is encountered	1	Broken backs often cause blade breakages in current manual operations and this has the potential to be worse in automatic operations.	0
Noise level	Potentially higher that band saw but still at acceptable levels when noise reduction saw blades are used.	0	These currently operate at acceptable noise levels	1
Replacement/consumables saw blade cost	It has been difficult to obtain definite data on longevity of circular blades in beef splitting/cutting application. Hence using the NCMC scribing project as reference, Scribing Circular blade cost = 367 Euro = A$550, estimated carcases cut with this blade = 4000. Therefore cost per carcase = $0.14	0	Blades approx $10 each. 8 blades /shift (4 per saw at Swift Dinmore, 1675 head), time to replace blade negligible. Cost per carcase = $0.05.	1
Bone dust	Circular saw will create more dust than a band saw due to its thickness	0	Less than a circular saw	1
Water useage	Equivalent to Band saw	0	Equivalent to Circular saw	0
Saw cost	More expensive than band saw blades	0	Cheaper than circular saw	1
Cell footprint	Smaller footprint than band saw	1	Larger foot print needed for band saw	0
Cleaning	Easier to clean that band saw, clean like brisket cutting saw	1	Harder to clean , have to open side covers	0
Robustness	Tool is structurally rigid	1	Tool prone to flexing and damage under impact	0
Complexity	Less operating parts	1	More moving parts and more difficult to set up and maintain.	0
Cutting accuracy	Circular blade is rigid in construction allowing for ideal tracking ability	1	Band saw is more prone to flexing and hence loss of tracking	0
Proven operation in automated operations	All current automatic Beef Splitting system utilise circular blades.	1	No operational automated system currenly uses a band saw for any species	0
Proven operation in other species	Currently used in Pork splitting operations. MAR currently trialing circular saw for Lamb splitting.	1	No operational automated system currenly uses a band saw for any species	0
OH&S risk	Minimal OHS risk, with blades being replaced during non production periods.	1	Potential risk from breaking blades and the hazard caused in replacing blades during production.	0
TOTALS		**10**		**4**

4.2 Saw Development setup and trial at MAR

The images and discussion below detail the iterative design of the beef splitting saw that took place following the decision to pursue the circular saw concept in preference to the band saw.

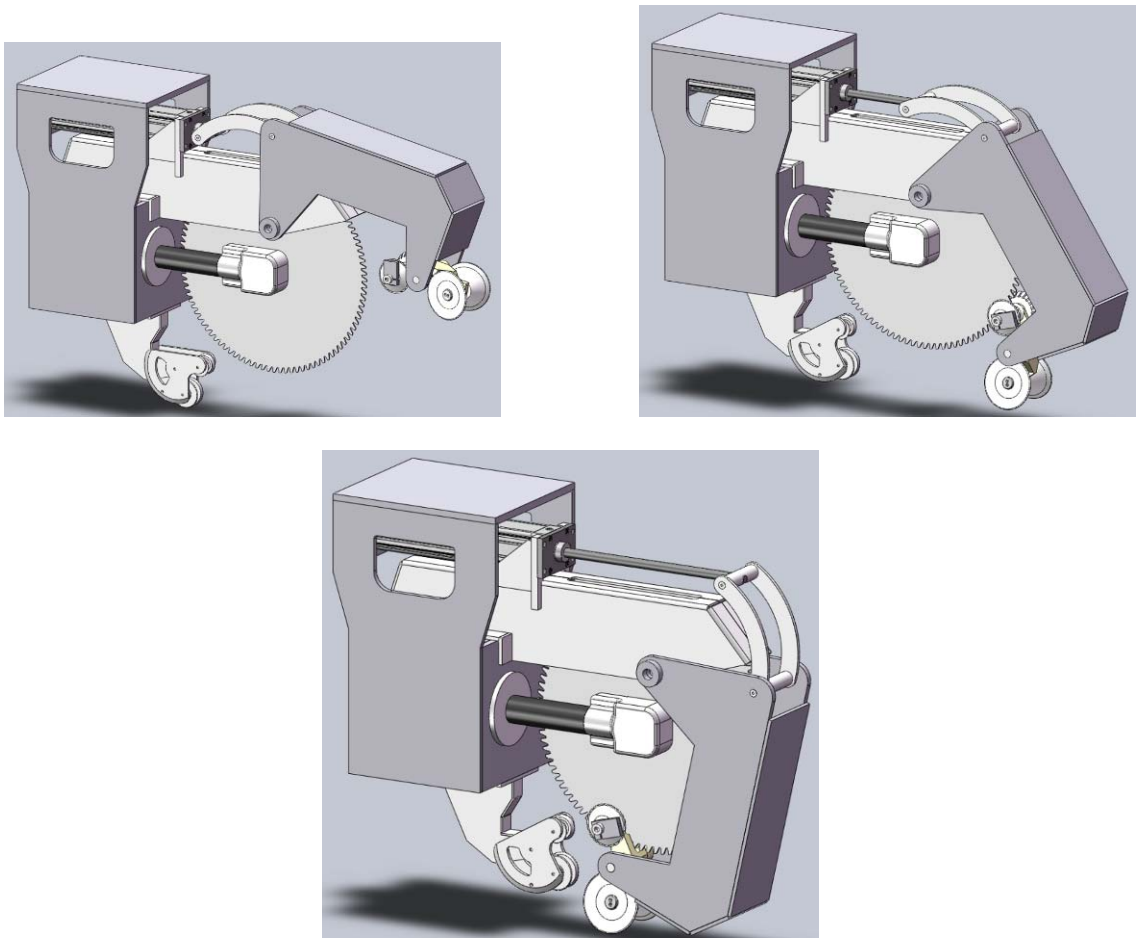


Fig.2 Concepts for Circular Guidance Mechanisms

The images above show the initial design which was based on the design of the saw used for Lamb Splitting trials in a concurrent project. Issues noted with this design, however were the flimsy appearance of the cylinder and actuation arm for the front clamp and the height of the box surrounding the saw motor. The box has the potential to collide with the rail supporting the carcase and, with its open face, to lead to entrapment of meat and bone dust causing hygiene issues.

Modifications were made to the design to incorporate the cylinder to lift the front clamping arm into the structure of the arm, improving strength, decreasing the profile of the saw and enclosing the motor to minimize entrapment issues. The larger wheels were also moved to the fixed clamp position as it was decided to approach the carcase from the back of the animal rather than the open side of the carcase. This would avoid having a large part of the saw 'inside' the carcase when

performing the cut and decrease the potential for the saw to ‘catch’ on various parts of the carcase. The images below show this.

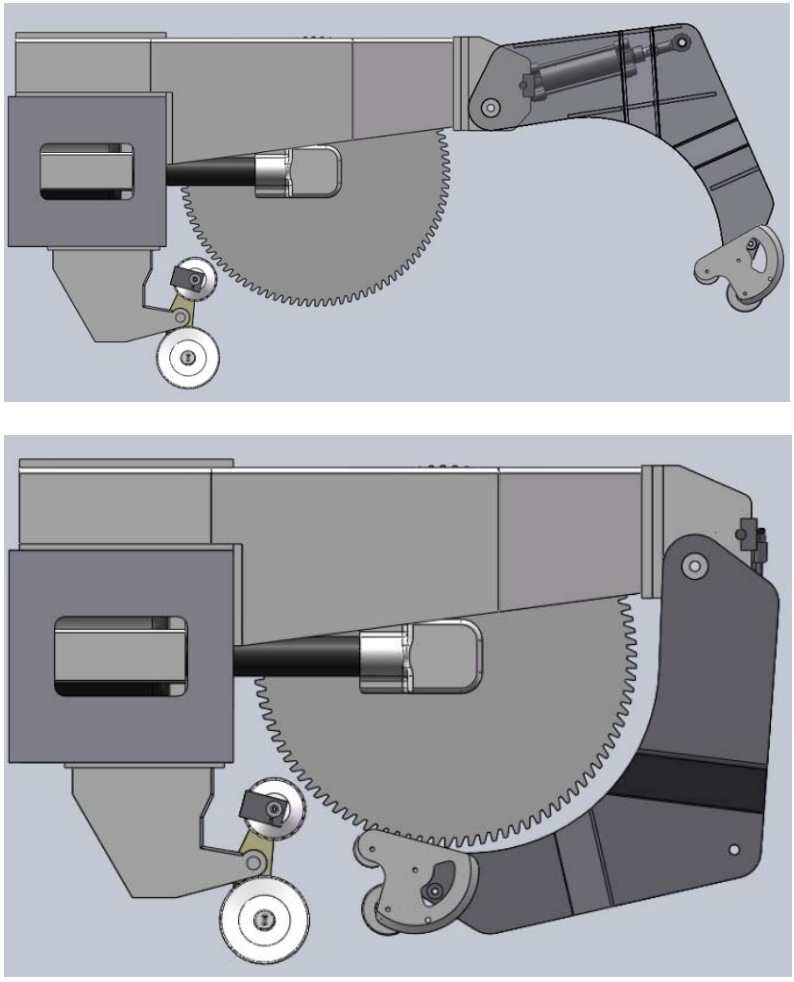


Fig.3 Revised design

The final design, shown below refined the design in the figure above, fully housing the motor and tapering the main structure to avoid it catching on the carcase, it is shown below.

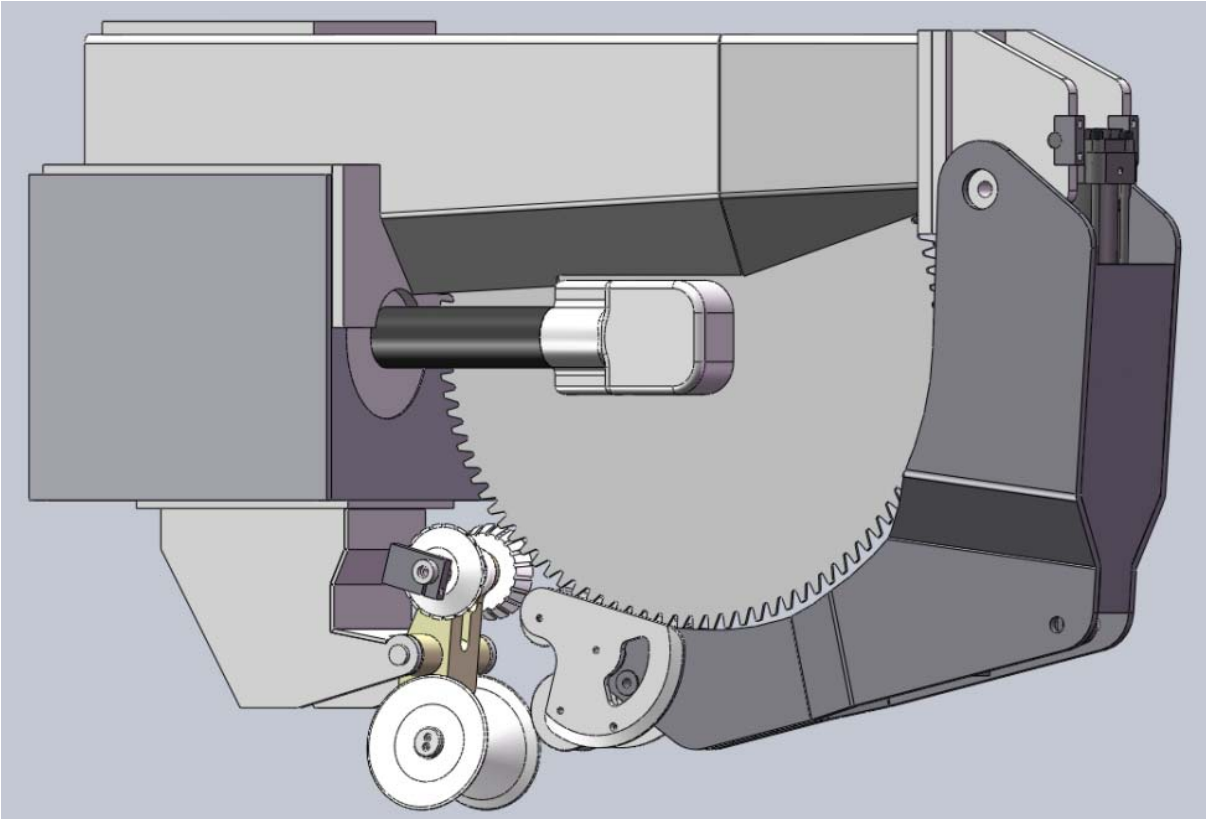


Fig. 4 Final design

Manufacture of the saw followed the completion of this design the completed saw is shown below mounted to a robot in MAR's work shops.

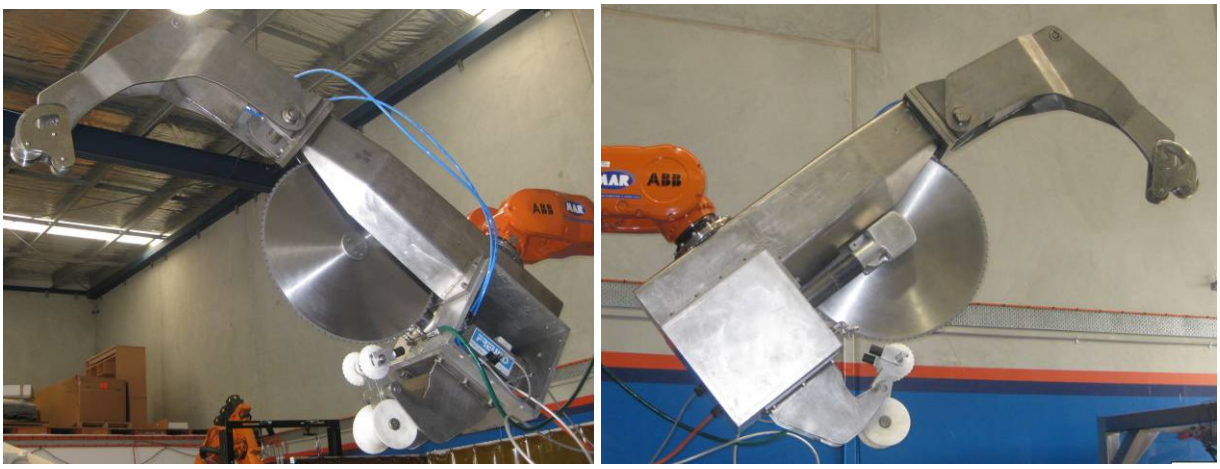


Fig.5 Saw mounted on Robot at MAR

Dry cycle testing of the tool was conducted as well as the splitting of a single carcase. Videos are attached to this report showing these trials. It will be noted in the splitting of the actual carcase that the saw is at a large angle and in reality would collide with the meat rail in a real abattoir. The dry cycle video with the cardboard cutout to simulate a carcase shows that the saw can be manipulated so that it easily maneuvers through the legs of the carcase without hitting the rail above.
Further improvements were be made to the saw prior to site trials, these will saw a stronger cylinder installed as well as modifications to the pivot point of the cylinder to ensure the front clamp is held out straighter as the saw approaches the carcase reducing the need for robotic manipulation to maneuver it through the carcase legs. The improved saw is shown in the next section.

4.3 Installation and Trials On site

EC Throsby granted MAR permission to conduct trials for this project in one of their chillers on site at their plant in Singleton NSW. The robot and support equipment were transported site and installed. The images below show the leg spreader and robot setup ready for these trials.

Fig.6 Side view of robot setup at ECT

Fig. 7 Front view of robot setup at ECT

Fig. 8 Carcase Leg Spreader setup at ECT

Trials were conducted and these are shown in the accompanying videos. The front and rear roller guidance system worked well down the majority of the length of the carcase. Issues were encountered in the neck area where the boss of the saw motor, which exists on one side of the saw blade but not the other as shown in the figures below, is in full contact with the carcase.

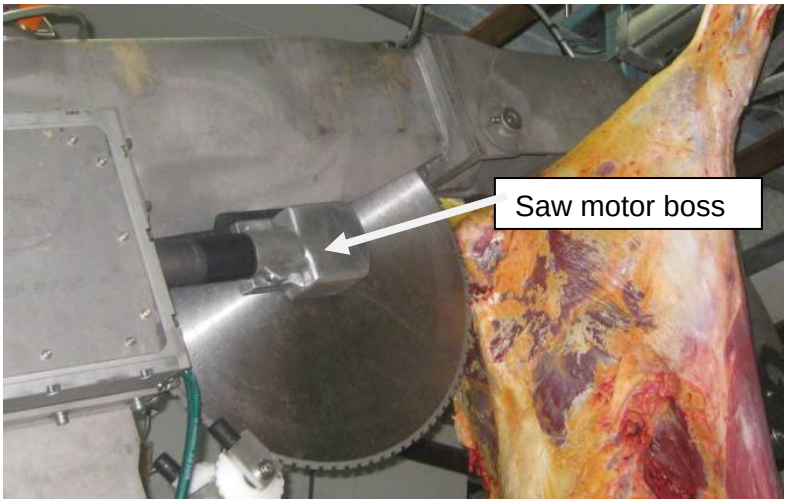


Fig 9 Saw motor Boss on one side of the saw blade

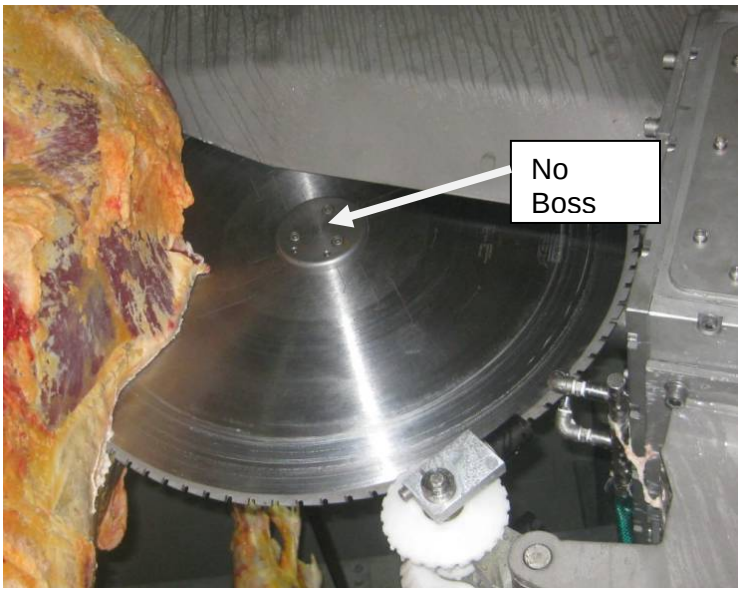


Fig. 10 No Boss on the opposite side of the saw.

The effect of this is that with the saw contacting the carcase unevenly on each side of the split and tends to skew the carcase to one side, see figure below, and cause soft siding in the neck area.

Fig.11 Skewed Carcase

Following the splitting of 5 carcases with similar results the decision was made to return the saw to MAR to have guards made up to cover the saw boss with an identical cover on the other side of the saw so that the skewing of the carcase is eliminated. These guards are shown in the figure below.

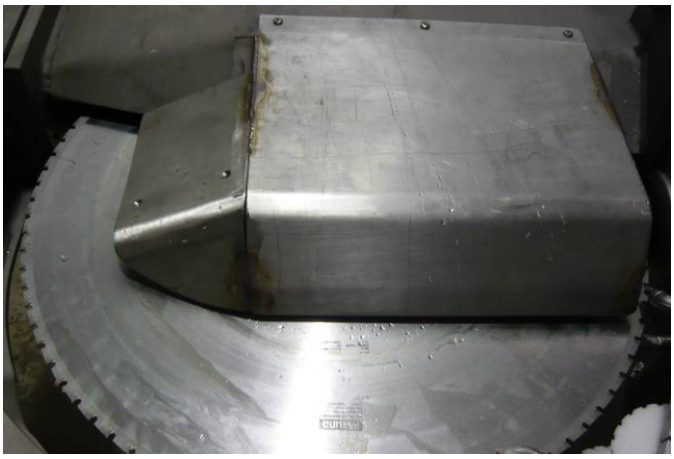


Fig.12 Guarding to eliminate carcase skew

This guarding succeeded in eliminating the skewing of the carcase but had issues with the carcase flesh and bones getting caught between the saw and the guarding and the guarding flexing and touching on the saw blade as the saw attempted to push through the carcase.
Again the saw was returned to Sydney and the guarding remade, this time with thicker material and more support. The images below show the new guarding. It can be seen that in comparison to the first version it is a 'neater' fit around the boss, there is more saw blade at the front of the saw to allow more of the carcase to be cut before the guarding try's to push through the carcase and that nylon has been fitted to the rim of the guarding to inhibit any metal on metal rubbing should the guards flex.

Fig.13 New guarding

Following the fitting of the new guarding the saw was transported back to EC Throsby and further trials were conducted. These trials yielded mixed results. Some cuts tracked the spine for the majority of the length of the animal but went off line around the neck area. Various clamp pressures were tested, the thinking being that the pressure of the internal rollers on the meat around the neck was causing the meat to be squashed and hence contributing to the soft siding being experienced. However no significant change was noticed.
On other cuts the saw struggled, due to the width across the saw blade created by the new guards, with clearance around the inside thigh area causing the cut to be jerky (see videos) as the guards forced the carcase apart causing a poor cut result.
Variations in the cutting technique were experimented with, these included:

- Angling the saw up as it passed through the legs of the animal in an attempt to cut more of the thigh area before the guards contacted the area.

- Once the saw had passed through the legs and the rear rollers had contacted the back of the carcase, cutting some of the carcase before clamping the front rollers in an attempt to allow the carcase to more easily spread apart.

However these variations had limited success.

Design team discussions at this point established that there were two main modifications that could be made to the saw that may assist the cutting process:

- Use of a larger blade, this would allow more of the carcase to be cut and spread before the saw guards came into contact with the carcase.

- Modification of the rear rollers to force the cutting of the back bone to occur in a more central position on the blade.

Both of these options would mean extensive redesign of the existing saw and the option of adapting an existing band saw for trials instead was considered. The band saw that was previously used at Ralphs Meat in Victoria for a FSA project was available and already setup to be mounted to a robot. MAR made the decision to trial this saw by modifying it to incorporate front and rear rollers as had been done with the circular saw. At this point it was felt that since the band saw is the most common type of saw used in manual Beef Splitting, trialing this would at least confirm the ability of the of the roller guides to track the spine and produce a good split. The images below show the design drawings for this:

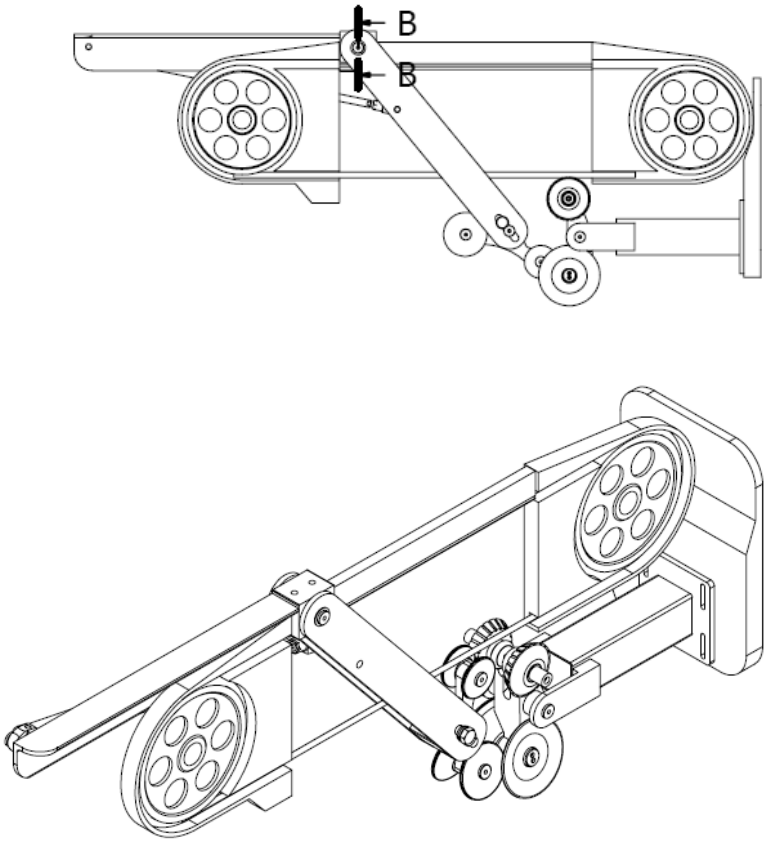


Fig.14 Design for Bandsaw with Guidance Mechanism Fitted

The manufactured modified saw is shown below:

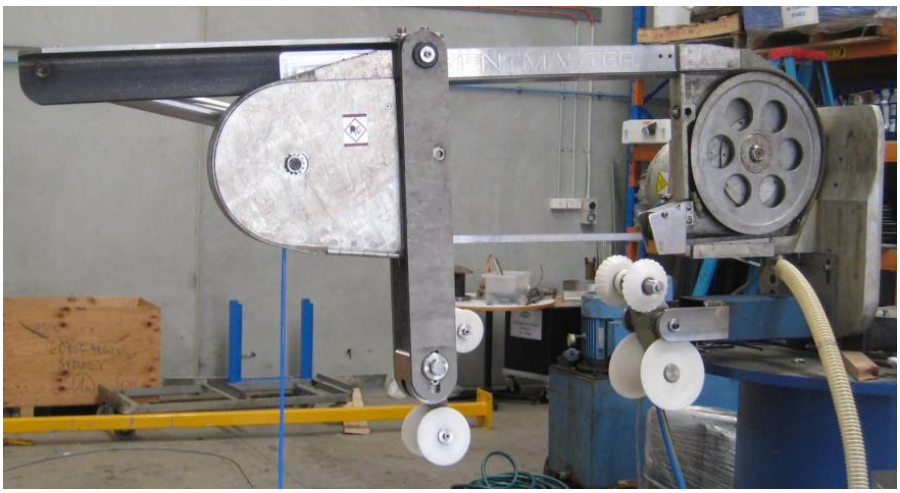


Fig.15 Bandsaw with Guidance Mechanism fitted
This saw was shipped to EC Throsby and further trials were conducted.

Fig. 16 Setup with Bandsaw at EC Throsby

Seven carcases were split during the trials with this tool. These all performed well during the initial part of the cut however soft siding occurred again in the neck area. On the final two carcases one set of wheels on the back rollers were replaced with a wedged shaped guide (shown below), the thinking being that the rollers were too small for the larger animals being split. This provided a slight improvement but soft siding was still evident.

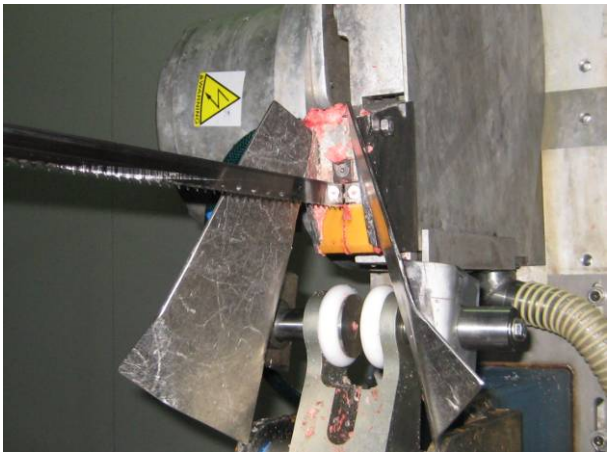


Fig. 17 Wedge Shaped Guide

5 Success in Achieving Objectives

Through the course of this project we have investigated incorporating a carcase guidance system with both a circular saw and band saw. We have achieved a limited success in that for the majority of the cut the guidance mechanism successfully guides the saw down the centre of the spine. However it has been found that in the neck area of the carcase the trialled roller guidance system fails to guide the saw through the centre of the neck area and soft siding occurs in the feather bone region.

5.1 Saw/Tool life

Due to the issues we had with soft siding, a limited number of carcases were split during these trials. Trials with the circular saw used a tungsten tipped blade, however due to the limited number of splits tool life remains an unknown for production levels of cutting.
Band saws are currently commonly used for beef splitting with blades being replaced once per shift.

6 Conclusions and Recommendations

From the trials conducted it is evident that mechanical guide mechanism manufactured is successful to a limited extent. Use of the front and rear roller mechanisms has meant that the carcase backbone can be successfully tracked where the back bone is clearly defined, however when the backbone is not clearly defined as in the shoulder and neck area the roller guidance concept does not work successfully and soft siding occurs.

6.1 Technical Review

Following the trials a technical review of the system was conducted with John Hughes. John is considered an industry expert having worked in the Australian Meat Industry for over 50 years and been involved in some of the more momentous events in the industry during that period. The following points/recommendations are those to come out of this review.

- Better neck guidance is required, possibly using spring loaded plates to guide the saw through the neck area.

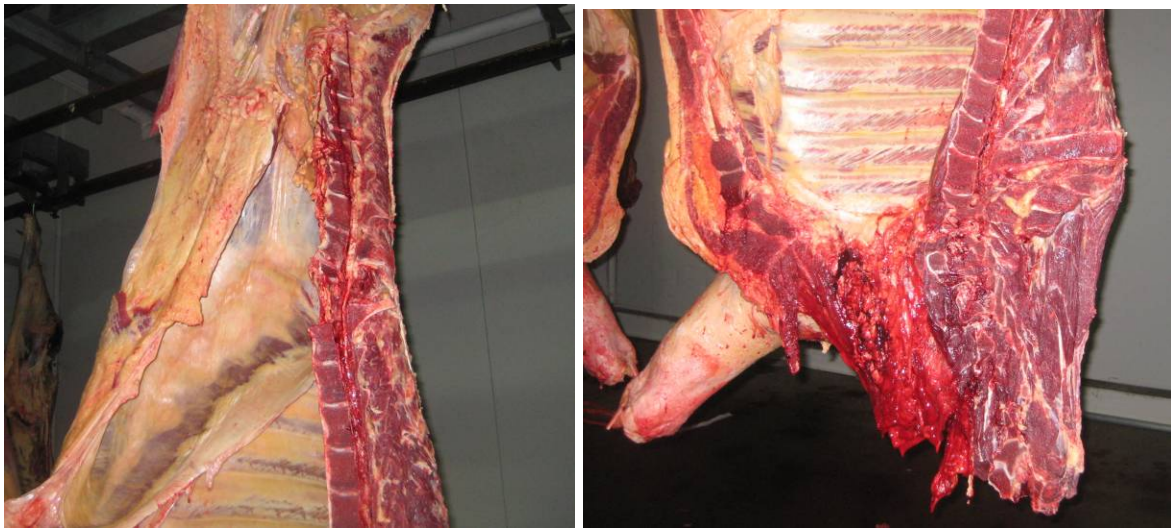


Fig. 18 Carcase successfully split down the majority of the body but with soft siding in the neck area.

It can be seen from the above images that the tracking of the carcase down the majority of the length of the spine has been good. However once the blade reaches the neck area, even with the wedge shaped guide, that soft siding is experienced. It was witnessed during the trials that when the saw reaches this fleshier area of the neck the meat is ‘squashed’ out of shape between the inside rollers and the outside rollers or wedge shaped guide and this causes the soft siding to occur. Reducing the clamping pressure as the saw entered this area did not seem eliminate the effect. It is felt that if the two outside rollers were made into larger wedge shaped guides that were spring complied where by they were able to open up as the saw entered the fleshy neck area but still centralize the cut, better results may be achieved.

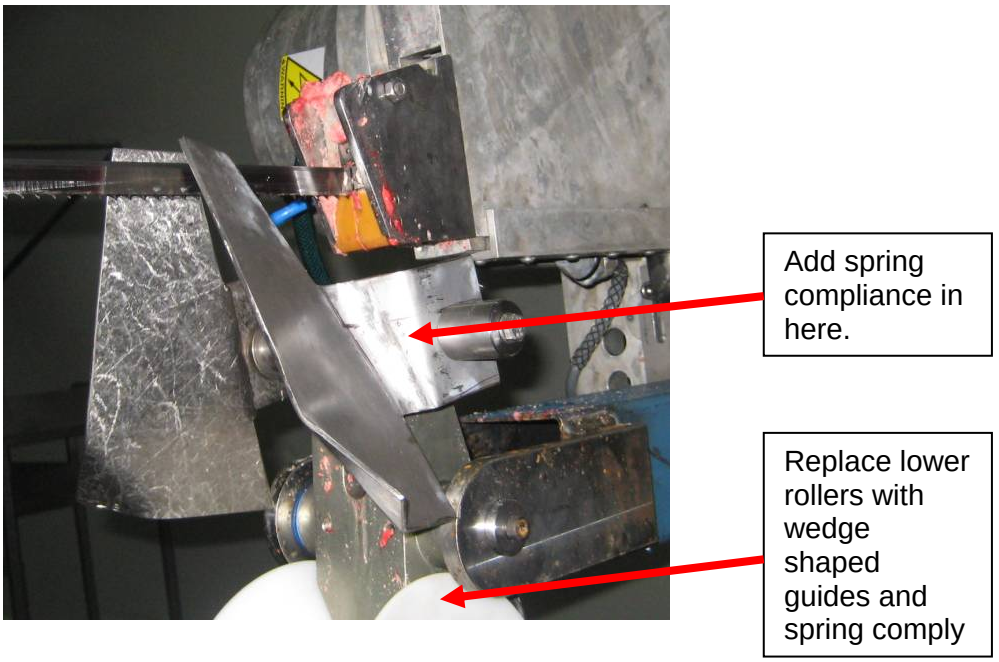


Fig. 19 Wedge Shaped Guide showing where spring compliance should be added

- The internal guidance rollers require a design review, it was felt that the shape of the rollers may have been causing them to 'bottom out' on the vertebrae inside the carcase. It was suggested that the shape of these needed modification to correctly track the vertebrae column.

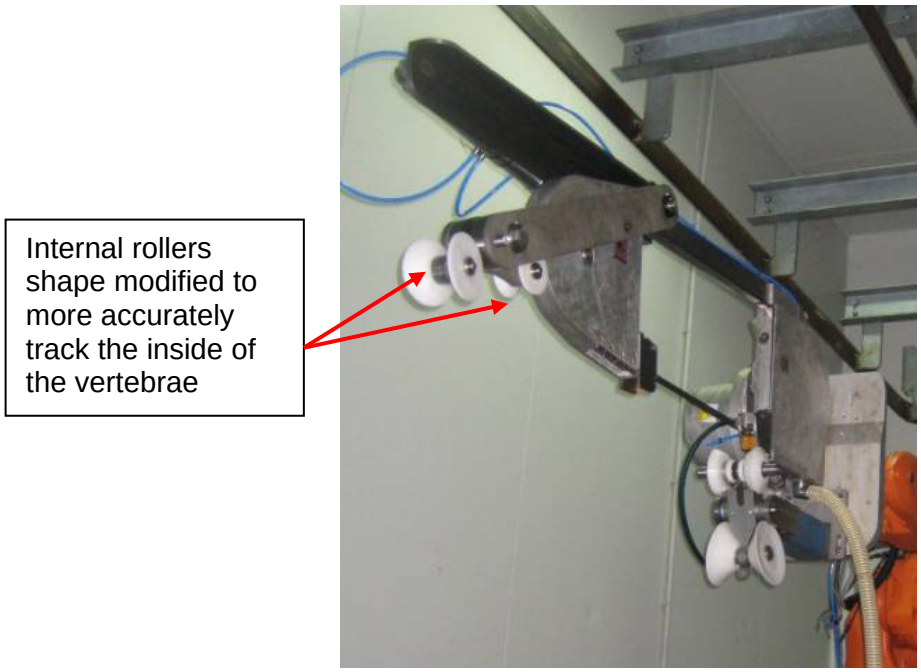


Fig. 20 Modifications required to internal rollers

- The hind legs need to be opened sufficiently by spreader to crack the aitch bone before the saw begins to split. As can be seen from the image below the spreader used did spread the legs but not enough to break the aitch bone. This was not an issue with the band saw due to its narrow profile however as can be seen from earlier discussion could have been an advantage in getting the circular saw into the carcase.

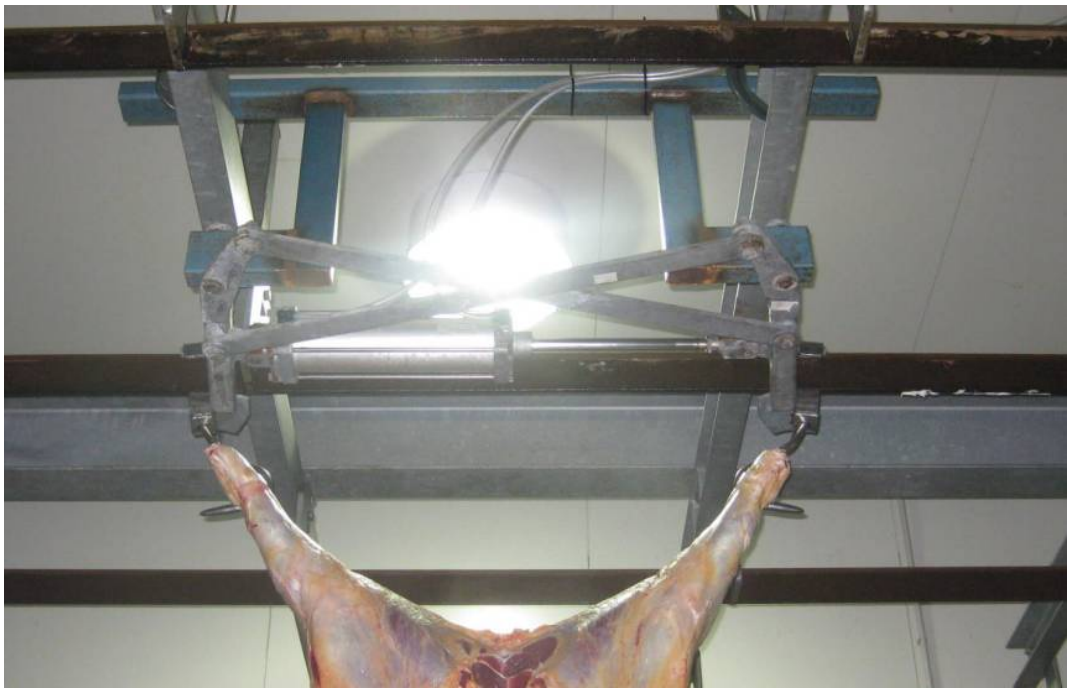


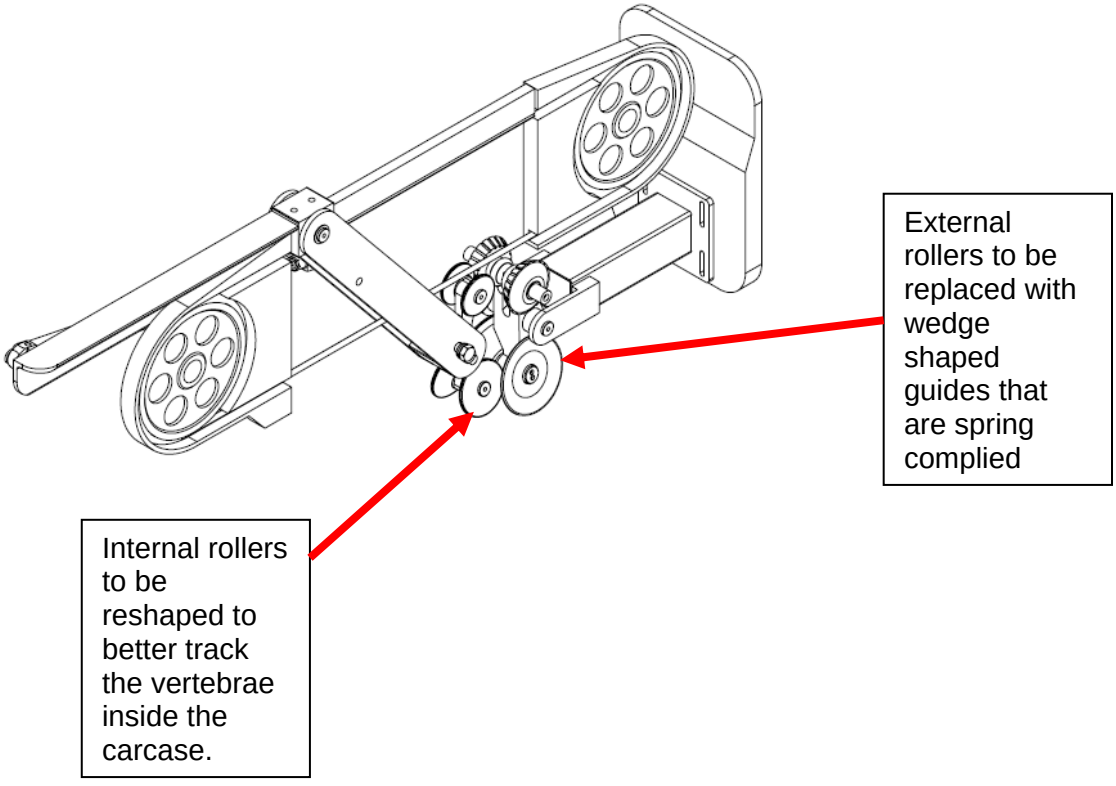
Fig. 20 Leg spreader installed at ECT

6.2 Moving forward

As a result of the technical review the following are seen as the next steps in proving the ability of The Automated Beef Splitting system to successfully split a beef carcase:

- Redesign the rollers that currently run down the outside of the carcase. It is recommended that these are designed as spring loaded wedge shaped guides that are able to comply more successfully with varying body shapes than the existing rollers.

- Redesign of the rollers that run down the inside of the carcase. These need to be modified to ensure they track the vertebrae on the inside of the carcase correctly.



MAR currently has a Stage 3 project proposal lodged with AMPC/MLA to continue the development of this bandsaw guidance mechanism with a view to eliminating the occurrence of soft siding in the neck and shoulder area. Design, manufacture and on-site trials at a suitable location able to present beef carcases for trial on a regular basis is important and will lead to successful completion of this project and development of a fully automated beef splitting system.

The objectives of the proposed project are:

- To produce improved design to current mechanical neck guidance
- Find a suitable test site (beef processing plant) for beef split trials able to present carcases for trials
- Manufacture new mechanical guidance system
- Adapt new mechanical guidance system to robot mounted bandsaw
- To perform robotically operated proof of concept trials and on-site splitting trials
- Demonstrate capabilities of new beef split tool

Technical challenges that are to be addressed during this project are;

- Ensuring tool guidance can perform as well for neck and shoulder as per majority of splitting down spine.
- Ensuring hind legs are spread sufficiently to crack the aitch bone before the saw begins to split
- Design of guidance must suit processing speed and sterilisation requirements.

The preliminary budget for this project is $315,000 and the outcome is to develop the splitting saw system so as to enable the next stage, Implementation of an Automated Beef Splitting System into a processing plant, to be realised.

P.PSH.0526 Beef Splitting Stage 2 Final Report Appendix 1: Trial results

Date	Carcase Number	Cutting method	Result/Comment
9/09/2010	1	Circular saw with roller guides, no guarding on sides of saw	Soft siding due to saw boss
	2	Circular saw with roller guides, no guarding on sides of saw	Soft siding due to saw boss
	3	Circular saw with roller guides, no guarding on sides of saw	Soft siding due to saw boss
	4	Circular saw with roller guides, no guarding on sides of saw	Soft siding due to saw boss
	5	Circular saw with roller guides, no guarding on sides of saw	Soft siding due to saw boss
13/09/2010	1	Circular saw with roller guides, side guards on saw	Carcase caught on side guarding, saw struggled (due to guards on side of saw) to pass through the spread legsof the carcase resulting jerky movement of carcase and a poor cut. Carcase jammed in guards on way down carcase
	2	Circular saw with roller guides, side guards on saw	Carcase jammed on side guards as saw passed through legs
23/09/2010	1	Circular saw with roller guides, new side guards on saw	Carcase caught on side guarding, saw struggled (due to guards on side of saw) to pass through the spread legsof the carcase resulting jerky movement of carcase and a poor cut.
	2	Circular saw with roller guides, new side guards on saw	Carcase caught on side guarding, saw struggled (due to guards on side of saw) to pass through the spread legsof the carcase resulting jerky movement of carcase and a poor cut.
28/09/2010	1	Circular saw with roller guides, new side guards on saw, modified saw approach and cut path	Saw struggled to push through legs, slightly twisted carcase, saw got off line cut into the ribs
	2	Circular saw with roller guides, new side guards on saw, modified saw approach and cut path and lower clamp pressure	Saw struggled to push through legs, jerky cut, soft siding in neck area
	3	Circular saw with roller guides, new side guards on saw, modified saw approach and cut path and lower clamp pressure	Saw struggled to push through legs, jerky cut, saw jammed

	4	Circular saw with roller guides, new side guards on saw, modified saw approach and cut path and lower clamp pressure	Saw struggled to push through legs, jerky cut, soft siding in neck area
	5	Circular saw with roller guides, new side guards on saw, modified saw approach and cut path and	Saw jammed on pelvis bones
8/12/2010	1	Bandsaw with roller guides	Soft siding in neck area
	2	Bandsaw with roller guides	Soft siding in neck area
	3	Bandsaw with roller guides	Soft siding in neck area
	4	Bandsaw with roller guides, lower clamp pressure	Soft siding in neck area
	5	Bandsaw with roller guides, lower clamp pressure	Soft siding in neck area
	6	Bandsaw with wedge guides, lower clamp pressure	Soft siding in neck area, jerky cut due to broken back
	7	Bandsaw with wedge guides, lower clamp pressure	Soft siding in neck area