finalreport

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Wodonga Abattoir 6 Way Cut Automation

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

Abstract

The design and development of a fully automated 6 Way Cut system will address the need to eliminate bandsaw use and in turn produce sizeable benefits in relation to OH&S and processing efficiencies including eliminating sawdust, product shelf life, yield and presentation. It will also provide the potential to reduce carcass shrinkage caused by chilling by enabling hot processing of the carcasses. Hot processing is currently not performed manually at Wodonga as it is considered too dangerous.

Executive Summary

The design and development of a fully automated 6 Way Cut system will address the need to eliminate bandsaw use and in turn produce sizeable benefits in relation to OH&S and processing efficiencies including eliminating sawdust, product shelf life, yield and presentation. It will also provide the potential to reduce carcass shrinkage caused by chilling by enabling hot processing of the carcasses. Hot processing is currently not performed manually at Wodonga as it is considered too dangerous.

Through this project MAR reviewed the manual 6 Way cutting process at Wodonga Abattoirs. Data on breed, size, weight and cutting accuracies was gathered, not just on goat (as was originally proposed) but on all species processed. This allowed the design and development of an automated 6 Way Cutting system that consists of a carcass gripper, carcass splitting saw and horizontal cutting saw. Trials were conducted at MAR's workshops in Sydney which determined there was a need for a third robot which deviated from the original two robot design. This change to a three robot system also saw a change in the expected cycle time. In reality this cycle time is higher than expected due mechanics and programming required to accommodate the range of carcass sizes processed at Wodonga. On medium sized carcasses the system will run at approximately 150 carcasses/hr. The system has been commissioned and is currently running in production at Wodonga Abattoirs.

Using data from the Final Report for Project P.PIP.0387, Ex-Ante CBA for Automated Goat Cutting, prepared by Greenleaf Enterprises, it can be seen the benefits now for Wodonga abattoir from using the Automated 6 Way cutting system include:

- The gain in carcass weight that could be achieved by processing the carcasses hot.
- Increased productivity due to a more consistent supply of product.
- Labour savings due to a reduction in band saw operations.
- Decreased chilling costs.
- Reduction in OH&S costs.

The above benefits would remain true for the Meat and Livestock industry moving forward but the success of this system now also provides the impetus to move forward with a Sheep and Goat cubing development project.

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Contents

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

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1 Background

Discussions where held between MAR and Wodonga Abattoir Feb 2011 in Wodonga and at the iMACA automation conference in Sydney to discuss development of an automated 6 Way Cut system. This was based upon MAR developments for small stock cutting and splitting and considered draft designs offered by both MAR and Wodonga Abattoir for automating the 6 Way process. Further to this, an AMPC industry working group meeting was held at MLA in July 2011 where the objective was to utilise the industry expertise to finalise the key system specifications, and obtain "buy-in" to the system in the future. As a consequence, MAR's Robotic Restrainer option was selected as the preferred concept. This project, highlighted below as **STAGE 4** in the development process associated with 6 Way cut and future cubing processes to be developed, was approved for execution after a number of discussions regarding the system scope, MAR and Wodonga scope of supply, system layout and performance criteria.

Stage 1 - Automated Six Way Cut Wodonga Abattoir Food Processing On Plant Trials 2006 - COMPLETED

Stage 2 - 6 Way Cut & Carcass Split Trials 2009/10 – COMPLETED

Stage 3 - 6 Way Cross Cut & Splitting Restrainer Trials MAR Trials 2011 – COMPLETED

Stage 4 - Robotic 6 Way Cut Automation for Wodonga Abattoir – THIS PROJECT

Stage 5 - Auto Sheep & Goat Meat Cubing Development Trials - FUTURE PROJECT

Stage 6 - Automated Sheep & Goat Meat Cubing System – FUTURE PROJECT

The following sections summarize each of the development stages completed above.

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Stage 1 - Automated Six Way Cut Wodonga Abattoir Food Processing On Plant Trials 2006

In 2006 MAR completed a 6 Way cut feasibility project working with Norvic Food Processing with very promising results.

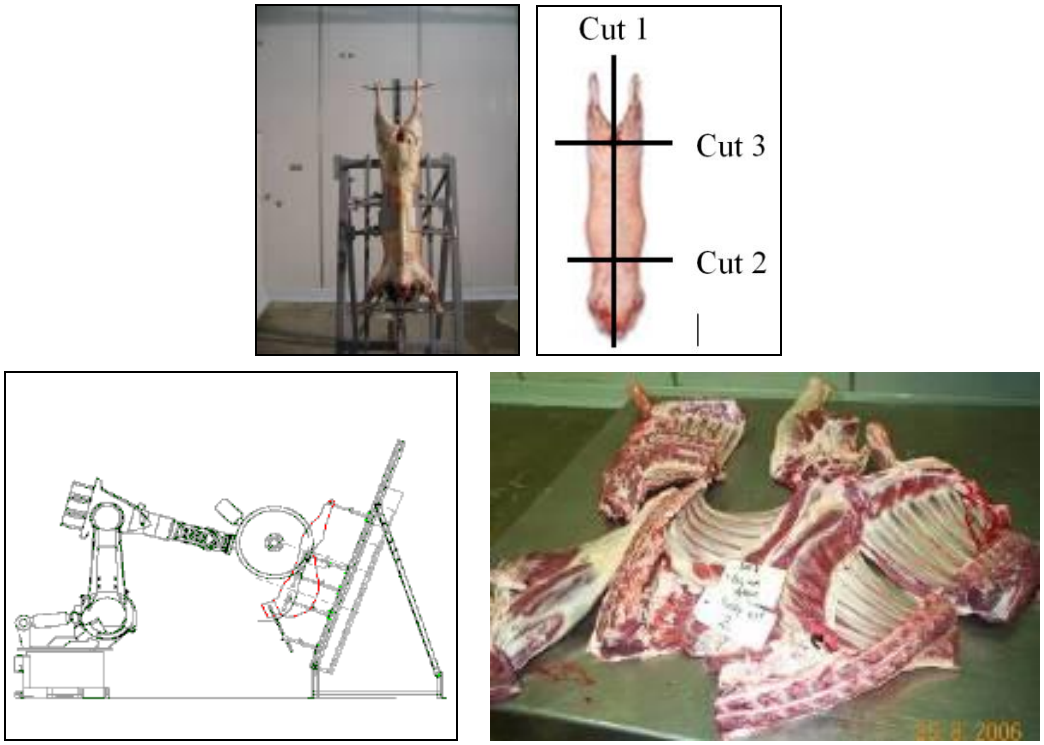

Figure 1 6 Way Hot/Chilled Cutting trials on goat with Norvic "P.PSH.205 6 Way Cut Trials"

Under sterile conditions a robot with a Freund Dustless Knife Blade fitted and a trial carcass stabiliser was used to test the blade speed, cycle time and effectiveness of the system. Cycle time data, videos and photos where recorded to reflect the results.

The results of these trials proved that using a rotary dustless knife blade can effectively achieve a 6-Way cut solution. This is providing that the blade is robotically controlled and the carcass is restrained in position to prevent hot meat being dragged through blade which also results in excessive bone shatter. The Freund circular-saw blade does not burn the meat, considerably reduces bone dust, shows no sign of bone shatter. It can also cut through HOT or CHILLED meat. A report was issued to the industry covering the first feasibility trial, Phase 1 of a robotic 6-way cutting system conducted on site at Norvic Food Processing, Wodonga.

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Stage 2 - 6 Way Cut 2 & Carcass Split Trials 2009/11

In 2010/11 MAR completed a project to develop a carcass splitting system for lamb, sheep and goat processing “P.PSH.0525”

Figure 2 Splitting Trial at MAR

These trails proved successful with the development of the smallstock carcass splitting tool suitable for splitting lamb, mutton and goat hot or chilled.

The design relies upon mechanical guidance removing the need for any complex and expensive sensing during robot operations.

MAR’s Carcass Splitter concept was designed primarily for two reasons:

- Lamb Splitting and
- Sheep, Mutton & Goat Splitting for 6 Way Cut.

Lamb production requires the design to provide good accuracy without any soft siding. The splitter is capable of providing a no soft side split for lamb and although this is not imperative for 6 Way Cut processing, it will provide better consistency in processed product. Accurate splitting also promotes stability of carcass for restraining and cross cutting.

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Stage 3 - 6 Way Cross Cut & Splitting Restrainer Trials MAR Trials 2011

Between Feb 2011 and July 2011 MAR performed self-funded in-house carcass restrainer and cutting trials

Figure 3 2011 Spilt Carcass Restraining Trials at MAR

These trials where used to demonstrate the concept for the 6 Way Cut Carcass Restraining and cutting.

Trails completed now provided a good platform to continue restrainer development within this Stage 4 PIP project with Wodonga Abattoir.

Stage 4 - Robotic 6 Way Cut Automation for Wodonga Abattoir

In this project MAR will work with Wodonga Abattoir to develop a fully automated 6 Way Cut system based upon Stage 1-3 developments for small stock cutting and splitting, and considering draft designs offered by both MAR and Wodonga Abattoir for automating the 6 Way process.

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2 Project Objectives

The design and development of a fully automated 6 Way Cut system will address the need to eliminate bandsaw use and in turn produce sizeable benefits in relation to processing efficiencies including eliminating sawdust, product shelf life, yield and presentation. It will also provide the potential to reduce carcass shrinkage caused by chilling by enabling hot processing of the carcasses. Hot processing is currently not performed manually as it is considered too dangerous.

MAR will work with Wodonga Abattoir to develop, manufacture, supply, install and commission a new Robotic 6 Way Cut System, designed to run at 300hd per hour, for Goat processing at Wodonga Abattoir based upon earlier Stage 1-3 developments for smallstock cutting and splitting.
This system will incorporate a basic design principle utilizing two ABB robots, robotic restraining concept, safety guarding, robot base, dustless blade cutting tool and sensing.

The project will focus on goat 6 Way cut processing and is primarily focused on reducing labour, removing operators from bandsaw operations, improving productivity efficiencies and eliminating saw dust to improve product yield, appearance and shelf life.

At the completion of this project whilst working with Wodonga Rendering, MAR will have provided the following outcomes:

- Conduct and review with Wodonga Rendering and MLA a full project Risk assessment documenting a detailed analysis covering technical, OH&S, process, schedule, financial, resource, design and commercial risks including action plans to deal with each identified risk throughout the life of the project

- Conduct review of 6 Way Cut process requirements detailing accuracies, breed, size and weight goat ranges processed at Wodonga.

- Development and trials of key system components as required during project progression.

- Performed 6 Way Cutting trials using robot mounted restrainer and MAR supplied components

- Manufacture, supply, development, installation and commissioning, of a Robotic 6 Way Cut System (300/hr) for Wodonga Rendering.

- Manufacture, supply, development, installation and commissioning, Robotic 6 Way Cut System components within project scope for Goat processing at Wodonga Rendering incorporating a basic design principle utilizing two ABB robots, robotic restraining concept, dustless blade cutting tools and sensing

- Full documentation including schematics and manuals

- Document performance including cut accuracies, quality and performance speeds.

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- Provide videos, reports and documentation detailing the development, its components and operational procedure to be provided for industry dissemination and promotional purpose
  Components to be supplied must meet process requirements and applicable Australian standards.

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3 Methodology

The following milestones will be achieved throughout the course of this project.

3.1 Initial Design & Project R&D

- Project risk assessment
- MAR will conduct and review with Wodonga Abattoir and 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.
- Submit proposed draft system design for approval
- Confirm scope of works for Wodonga Abattoir supplied equipment to ensure equipment meets design requirements for 6 Way installation
- Confirm schedules for MAR supplied equipment and works
- Confirm schedules for Wodonga Abattoir supplied equipment and works to ensure site is ready for installation

3.2 Process Design Review and Benchmarking

- MAR will work with Wodonga Abattoir to collect and review the following:
- Review current process (cut specs, weight range, breed, rates, process flow)
- Review of current manual process specification
- Performance and accuracy review of current manual bandsaw primal cut operations
- Document current cut accuracies, yield performance and process data

3.3 Robotic Carcass Gripper Manufacture, Development & Sensing Trials

- Design Robot Restrainer based upon data collected
- Manufacture robot mounted restrainer for proof of concept to be suitable for 6 Way Cut operations at Wodonga.
- Use of MAR hardware & software supplied for trials at Silverwater
- Perform 6 Way Cutting trials using robot mounted restrainer and MAR supplied components
- Use of MAR sensing system setup at Silverwater for trials
- Collect and analyse vision acquisition data to suit Wodonga Abattoir cut specification
- Document results and accuracies to ensure all cut specifications are met
- Document results and accuracies to ensure all cut specifications are met

3.4 Plant Layout and System Design

- Develop component and plant layout design based upon work to date including any trials
- Submit a working system design for approval by Wodonga Abattoir prior to build

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3.5 Order Major System Components

- Purchase of robot system components
- Purchase tooling and sensing system components

3.6 Manufacture & System Component Supply

- Purchasing of system components including tooling sensing, PC, safety and controls
- Manufacture of system components including tooling and adaptors

3.7 System Build, Setup & Testing

- System Build FAT at MAR
- Programming of robot and control system interfacing
- Mechanical & Electrical Setup & Test of System
- Test tooling robotic operated
- Integrate Sensing System
- Trial and troubleshoot of system
- Setup and test manual and semi auto and auto operations

3.8 System FAT at MAR

- Factory Acceptance Testing of system at MAR prior to shipment to site for installation
- Perform Cutting Trials
- Trial of cycle time
- Videos, reports and documentation of FAT
- System Operation and Design Review
- Videos, reports and documentation of FAT

3.9 On-Site Staged Installation of System

- Installation of robot(s), safety and auxiliary systems
- Additional Sensors, brackets, wiring, enclosures, Transport and installation materials
- Installation of sensing, tooling and controls
- Additional installation and expenses

3.10 System Setup Testing & Commissioning for Production

- Mechanical & Electrical Setup & Test of System
- Setup & Test safety systems
- Robot setup, programming and commissioning
- Test tooling robotic operated
- Setup and test manual and semi auto operations
- Setup and test full auto cycle operations of system
- Production trials of system
- Production and cycle time trials
- Site support & Operator Training

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3.11 Presentation Video, Documentation

- Two sets of documentation including Electrical Drawings, System operation procedures, Safety Audit and Risk Assessments and Operation manuals will be provided upon commissioning.
- System Videos, reports and documentation detailing the system, its components and operational procedure to be provided by MAR to MLA for industry dissemination and promotional purpose

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4 Results and Discussion

4.1 Initial Design & Project R&D

Attached as Appendix 1 to this report is the 'Project Charter' for this project. The Charter outlines the way in which the project will be conducted, the perceived risks, project responsibilities and proposed time line as well as design layouts. This layout is copied below and consisted of two robots and a single knife blade to perform both the vertical and horizontal cuts.

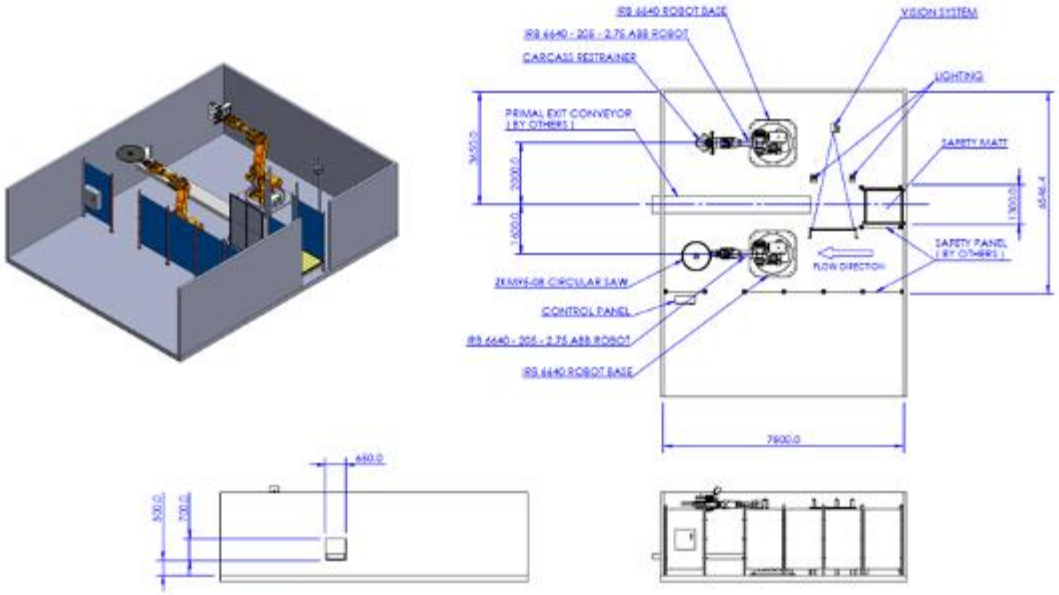

Figure 4 Preliminary design Layout of 6 Way Cut Cell

4.2 Process Design Review and Benchmarking

4.2.1 Process Review

In mid December 2013, Wodonga Abattoir supplied images and data in the form of the following table for MAR to develop a gripper design.

Species/Weight	Length	Depth	Circumference
Small Goat 9kg	126cm	32cm	72 cm
Large Goat 28kg	156cm	38cm	90cm
Large Sheep 42kg	140cm	38cm	111cm
Ram 56kg	174cm	50cm	112cm
Burnt Goat	105cm	28cm	58cm
Ram Shoulders Off	123cm		
Anzac Ram	100cm	38cm	
Anzacs	70cm		

From this data and previous experience gained from the ROC 450 project completed for GM Scott in Cootamundra, a gripper design was developed. It was felt however that more detailed data was required to confirm that this design was correct due to the large variance in carcass size experienced at Wodonga. MAR attended site during the week of 10/2/14 to gather more detailed information. The stick shown in the image below representing the gripper fingers (shaded areas represent the fingers, the non-shaded areas are the gaps between the fingers where the saw can cut) was taken to site to use as an indicator to determine whether the gripper that had been designed was suitable.

Figure 5 Gripper finger guide stick

Working with staff at Wodonga the following information was gathered on a range of carcass sizes and weights:

- Carcass length (from bottom of gambrel to tip of front legs)
- Carcass weight/ carcass type (sheep, goat, ram, mutton)
- Cut position (relative to the bottom of the gambrel), while the carcass was hanging from the gambrel staff from Wodonga placed a knife cut in the carcass to indicate where the 6 way cuts across the carcass would be made, these positions were then measured from the bottom of the gambrel.
- Gripper finger position (using guide stick above)
- Carcass circumference at each of the fingers
- Images of the full carcass and of the cut carcass, an example of the images taken are shown below.

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Figure 6 Gripper finger location compared to cut lines

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Figure 7 Cut dimensions

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From this data and the images taken the following table was been compiled and this was used to confirm the design of the gripper as shown on the following page.

Wodonga 6 Way Cut Carcass Data

				Cut Position (distance from top)				Carcass Circumference																		
Samples	Carcass	Carcass Length	Carcass Weight	Cut 1	Cut 2	Cut 3	Between Cut 1 & 2	Finger 1	ND	D1	W1	Avr.	div.	Finger 2	ND	D2	W2	Avr.	div.	Finger 3	ND	D3	D4	Avr.	div.	Finger 4	Finger 4 ND (Neck)
1	Goat No4	1300	21.4	540	985		445	480	153					610	194					740	236					790	251
2	Goat No5	1510	34.4	610	1120		510	570	181					780	248					970	309					970	309
3	Goat No5	1410	27.8	550	1030		480	480	153					750	239					910	290					940	299
4	Goat No5	1530	32	630	1060		430	590	188					750	239					950	302					930	296
5	Lamb	1210	17.6	460	870		410	480	153	200	160	180	27	570	181	200	180	190	9	780	248	200	310	255	7	700	223
6	Goat No5	1520	35.4	610	1100		490	650	207	200	180	190	-17	810	258	240	290	265	7	960	306	200	420	310	4	990	315
7	Goat No5	1560		600	1050		450	520	166	180	120	150	-16	580	185	180	170	175	-10	870	277	190	380	285	8	900	286
8	Ram	1440	53	630	940	1250	310	680	216	242	156	199	-17	880	280	242	253	248	-33	1140	363	413	368	391	28	880	280
9	Mutton M3	1550	23	570	1120		550	500	159	190	110	150	-9	680	216	210	200	205	-11	940	299	210	370	290	-9	770	245
10	Mutton M3	1560	23	590	1060		470	480	153	190	95	143	-10	590	188	200	190	195	7	970	309	190	410	300	-9	770	245
11	Mutton M3	1460		530	970		440	450	143	200	110	155	12	540	172	200	140	170	-2	820	261	200	330	265	4	820	261
12	Mutton M3	1200	14.6	470	850		380	500	159	180	110	145	-14	560	178	170	190	180	2	720	229	170	270	220	-9	620	197
13	Mutton M3	1210	15	450	810		360	450	143	160	100	130	-13	390	124	150	110	130	6	700	223	170	260	215	-8	580	185
14	Ram	1500	53	620	920	1340	300	760	242	271	166	219	-23	970	309	200	271	236	-73	1140	363	370	346	358	-5	990	315
15																											
16	Heavy Mutton	1570		580	1060		480	640	204	250	120	185	-19	820	261	250	200	225	-36	1050	334	260	380	320	-14	950	302
17	M1 Sheep	1170		480	870		390	530	169	190	130	160	-9	520	166	190	130	160	-6	810	258	180	320	250	-8	720	229
18	M1 Sheep	1230		470	800		330	440	140	160	100	130	-10	390	124	150	90	120	-4	670	213	160	260	210	-3	620	197
19	M1 Sheep	1500		550	1000		450	480	153	190	100	145	-8	460	146	180	130	155	9	870	277	200	340	270	-7	780	248
20	G1 Goat	1140		450	790		340	410	131	140	100	120	-11	410	131	160	120	140	9	670	213	140	270	205	-8	580	185
21	G1 Goat	1240		480	840		360	380	121	135	85	110	-11	390	124	130	100	115	-9	680	216	160	290	225	9	680	216
22																											
	CARCASS Length	mm																									
	TOLLEST	1570																									
	SHORTEST	1140							MAX	271	180				MAX	250	290				MAX	413	420				
	RANGE	430							MIN	135	85				MIN	130	90				MIN	140	260				
									RANGE	136	95				RANGE	120	200				RANGE	273	160				
	CARCASS WEIGHT	Kg																									
	Max	53																									
	Min	14.6																									
	Between Cut 1 & 2	mm																									
	Max	550																									
	Min	300																									
	Robot Range from Gambril																										
	Upper Pos.	450																									
	Lower Pos.	1120	EXCLUDING 3rd Cut																								
	Range	670																									

Figure 8 Carcass data

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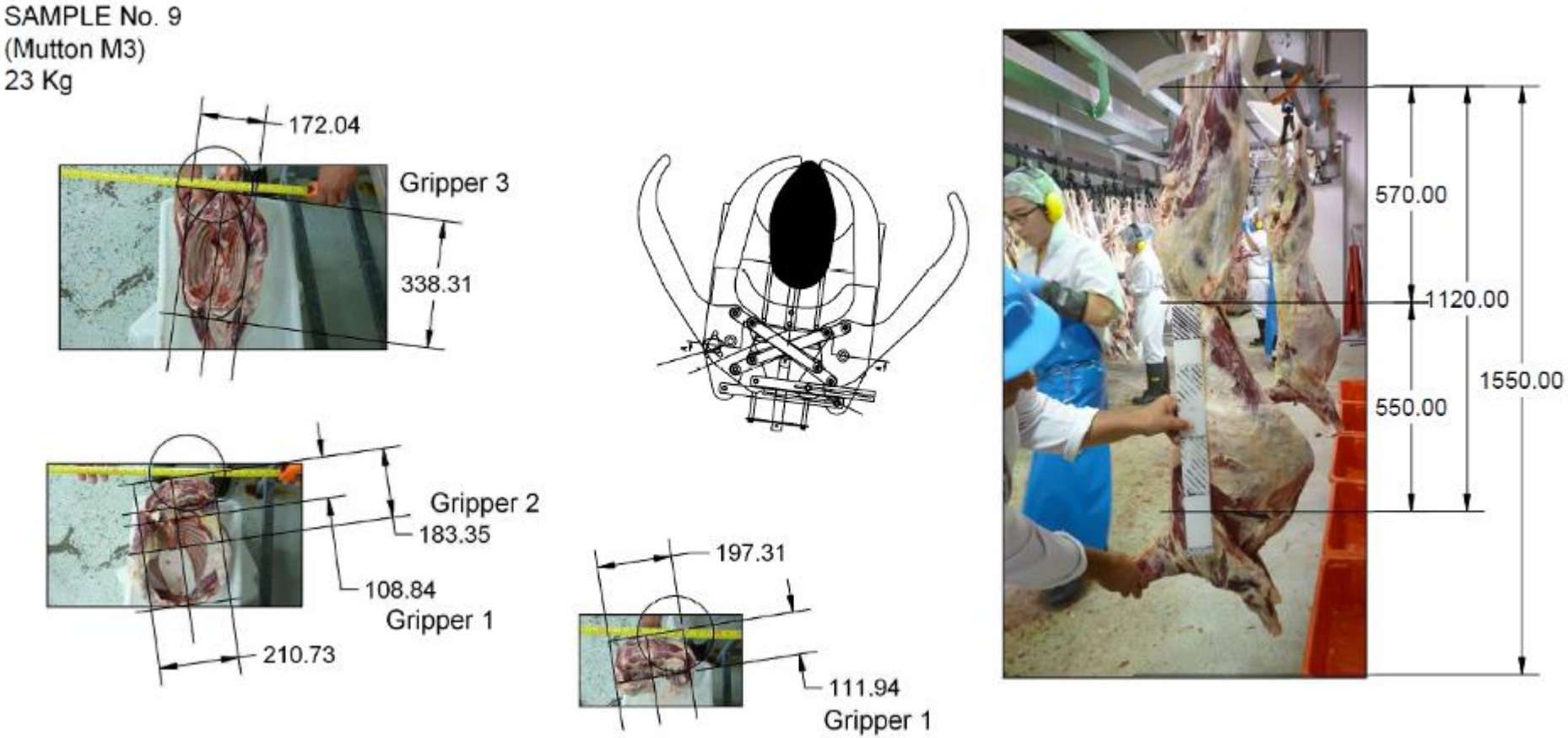

Figure 9 Gripper design using data from site visit

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4.2.2 Manual operations review

Using data from the Final Report for Project P.PIP.0387, Ex-Ante CBA for Automated Goat Cutting, prepared by Greenleaf Enterprises the current manual process of the room has the following specifications:

- 2 shifts per day with between 18 and 24 people
- 3.6 carcasses processed per minute for a 7.6 hour shift (3283 carcasses/day or 810,950/year)
- 10 cuts performed on bandsaws.

The manual operation was performed using carcasses that had been chilled for a full day. Chilling carcasses for this period of time results in chiller shrink of between 2.5 – 4.5% of carcass weight (as determined by previous trials conducted by the abattoir and stated in the Final Report of P.PIP.0387 Ex-Ante CBA for Automated Goat Cutting). The carcasses are chilled because it is not possible manually cut a warm carcass safely. Warm carcasses are hard to hold which increases the safety risk. The loss of weight due to chiller shrink will reduce as a result of using automation to break down warm carcasses.
The data collected for the CBA project showed that percentage shrink difference between automated (0.78%) and manual (2.11%) was 1.33% which results in a saving of $0.98 per head.

Other benefits to be gained from automating the 6 Way cutting process include:

- Increased productivity due to a more consistent supply of product
- Labour savings due to a reduction in band saw operations
- Decreased chilling costs
- Reduction in OH&S costs
- Reduction in saw dust losses

The graph below, from the final report for P.PIP.0387, Ex-Ante CBA for Automated Goat Cutting, shows the relative savings from each of these areas per head processed:

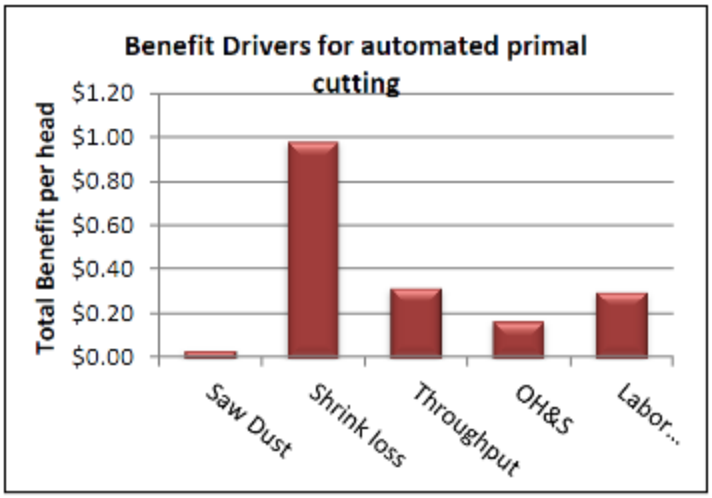


Figure 10 Benefits derived from automated primal cutting

In terms of cutting yields there is no yield benefit as a result of cutting accuracy for the 6 way cut process. The goat, mutton and ram markets purchase on a whole carcass price basis and do not differentiate prices for different cuts.

During the visit discussions were held with the Cutting Room foreman and Plant General Manager Jon Hayes. In performing the current manual operation for the fore quarter cut the bandsaw operator currently aims to cut between the 5th and the 6th rib. Feedback from Jon was that this accuracy was not a requirement of the Robotic system and the cuts should be sized so as to fit in the cartons used. It was also noted that the robotic system would be performing cuts straight across the carcass and not following the angle of the ribs as was done manually. From the data collected above it was determined that the cut positions could be taken as a percentage of the overall length of the carcass.

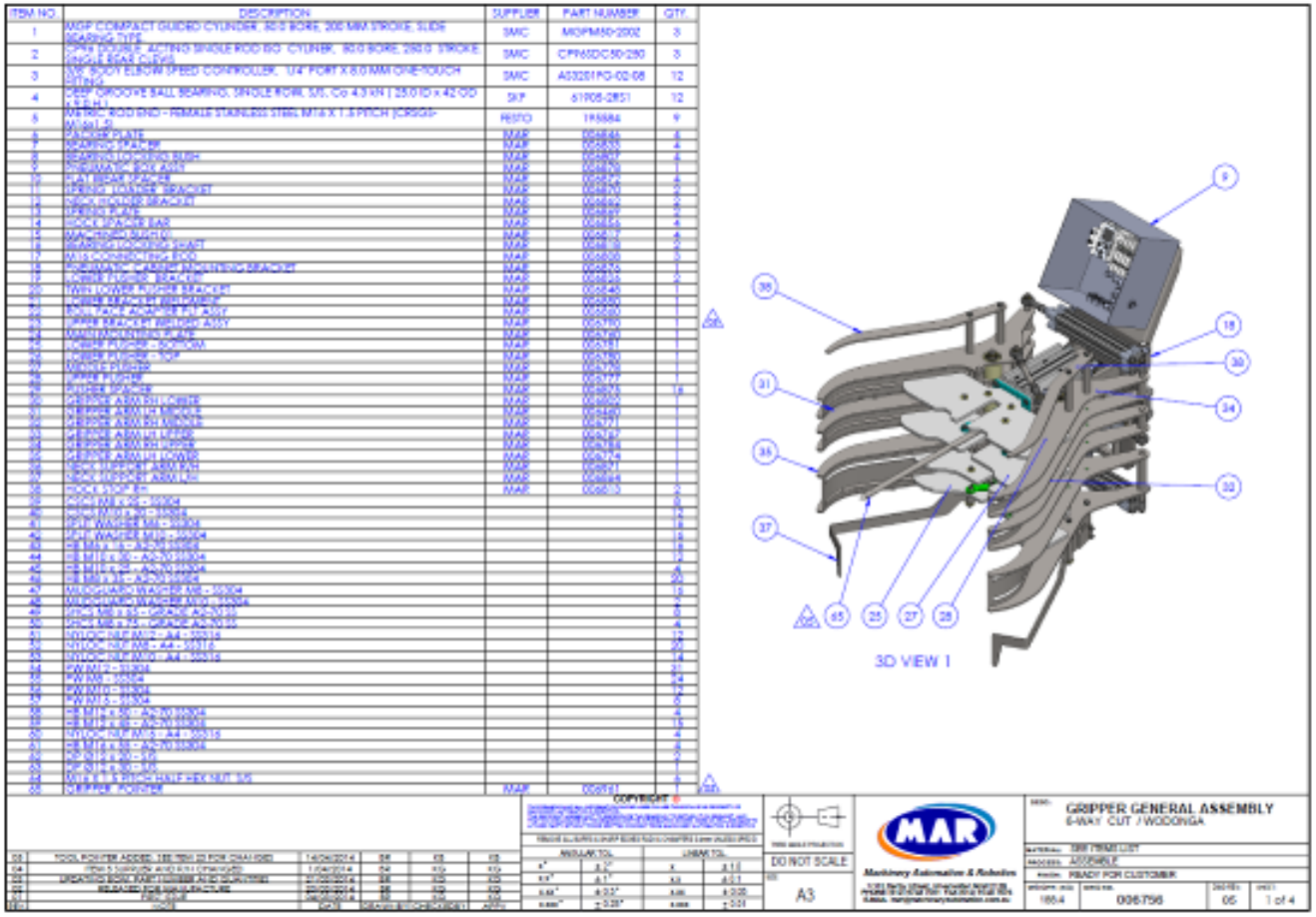
Discussions were also held with regards to the ability of the system to process partial carcasses or 'ANZACs' as they are called on site, some images of these are below.

Figure 11 Examples of 'ANZACS'

The outcome of the discussions was that these carcasses could be presented to the robot system but that there would be no guarantee that the part carcass would be cut into the desired pieces.

4.3 Robotic Carcass Gripper Manufacture, Development & Sensing Trials

Based on the data collected and shown in the previous section, the Carcass gripper was designed and built. The images below show the design.



12 Carcass Restrainer Design

The fabrication of the gripper followed the design. It can be seen from the images below, and the design drawings above, that in addition to the three main fingers, allowance had been made for extra arms attached the the top fingers to control the swing of the legs after a cut has been made and brackets incorporated to allow attachment of arms to support the neck if needed.

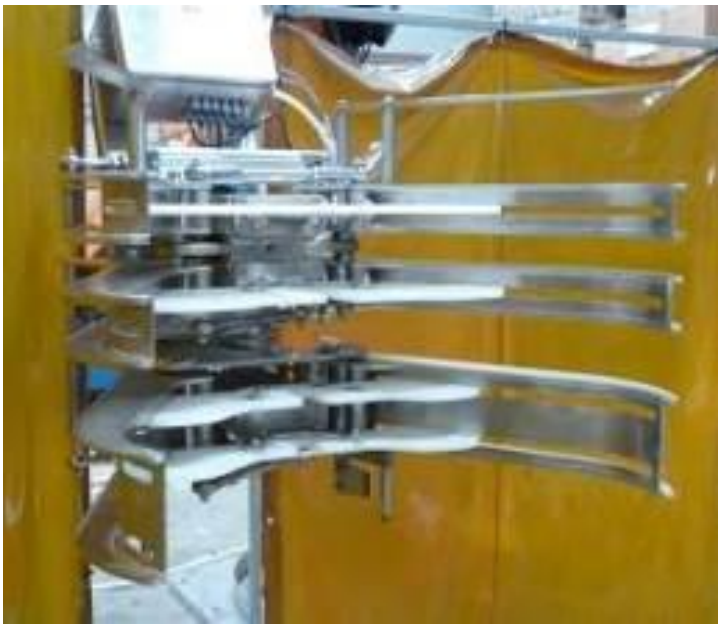


Figure 13 Fabricated Restrainer

The sensing system was setup and calibrated using sample carcasses indicative of the range of carcasses processed at Wodonga. Trials were then conducted using these sample carcasses and the fabricated restrainer in MAR's work shops. The images below show these trials in action.

Figure 14 Trials being conducted in MAR's workshop

The images below show some of the results from these trials. The first image is that of a medium sized goat (25 – 30 kg), it can be seen that the result is good from a portion size point of view but that there is some further work required to cut down the centre of the neck.
The second image is that of a large Ram (approx 60kg) which had its front legs removed and required an 8 way cut to be performed. It can be seen again that the portion sizes are good but that some refinement of the depth of cut for the lowest horizontal cut is required and again some work required to cut the neck more centrally.

Figure 15 Resultant cut of medium goat

Figure 16 Resultant cut of large Ram

4.4 Plant Layout and System Design

Following the above trials at MAR's offices, discussions with and site visits to Wodonga Abattoirs the Functional Specification and System layout were developed and approved by Wodonga. The layout took on the basic form of the preliminary layout presented above in Section 4.1, however more detail was provided on Control room location, fencing, safety mat, conduits and infeed and out feed

conveyors. The layout agreed to and the Functional Specification are attached and Appendices 2 and 3 to this report.

4.5 Purchase and manufacture of System Components and setup at MAR

Purchasing and manufacturing of system components followed Wodonga's approval of the layout and Functional Specification. The images below show the setup of the system in MAR's work shop.

Figure 17 System Setup in MAR's workshop

Figure 18 Control and operator panels interfaced to Robot Controllers

Figure 19 System Ready for cutting trials

4.6 Testing and FAT of the system

Trials and Factory Acceptance testing of the system commenced following the setup at MAR's Silverwater workshop. The initial trials were conducted using a 950mm diameter knife blade.

4.6.1 Trials with 950mm diameter Dustless Knife Blade

The image below shows the 950mm dustless blade mounted on the robot as well as a close up of the tooth pattern of the blade. The rpm of the blade is 94rpm.

Figure 20 950mm Dustless Blade setup and profile

The following issues were experienced with this blade during the trials:

- Tracking off spine at slow and fast speeds, blade bent away from hard spine and tracked down side of the spine.
- Blade struggled to perform horizontal cuts with both gripper components and robot moving with force of cutting blade

- Cuts tracking off neck when gripper was not supporting carcass.

Various modifcations were trailled including:

- Changes to pusher plates to secure carcass more uniformly, especially with smaller carcasses
- Changes to the holding pressure of fingers to relieve clamping pressure on blade.
- Changes to the robot program to release this pressure on the fingers as the blade travelled through the carcass.
- Changes to linear cutting speed
- Changes to cut angle and angle of approach

In addition, the speed at which the cuts can be made without causing the robot to fault on motion supervision meant that the desired cycle time was difficult to meet.
The below image is typical of the results that were achieved.

Figure 21 Typical result achieved with the 950mm dustless blade

With none of the attempted modifications having the desired effect of keeping the blade on the centre of the spine the decision was made to trial a toothed blade that had previously been used for Beef Splitting trials.

4.6.2 Trials with 720mm diameter toothed blade

The images below show the toothed blade and motor attached to the robot, along with the tooth pattern of the blade. The rpm of the blade is approximately 1000rpm.

Figure 22 720mm Toothed Blade setup and profile

As can be seen from the image below this blade was successful at spliting the carcass down the centre of the spine provided that the carcass was suitably supported.

Figure 23 Split carcass achieved with toothed blade

A drawback however was the amount of bone and meat dust produced, as can be seen on the inside of the spine in the image below.

Figure 24 Bone and meat dust produced using toothed blade

In an attempt to reduce the amount of bone and meat dust produced, water was sprayed on the blade while making the cut. There was however no significant difference in the amount of dust produced.
From a cycle time point of view the linear cutting speed achievable was faster than for the dustless blade and hence the desired cycle time was more likely to be achieveable.
With these results from the tipped blade and the large diameter dustless blade the decision was made to trial a third blade, another dustless blade with more aggresive cutting profile. This blade was infact the blade that was used during 6-Way Cut trials performed at Wodonga Abattoir several years ago but was not considered suitable for the project due to its smaller diameter (750mm) when the larger diameter (950mm) blade was available. It was considered that the smaller diameter blade would not be large enough to cut through the larger goats and rams.

4.6.3 Trials with 750mm diameter dustless blade

The image below shows the 750mm dustless blade mounted on the robot as well as a close up of the tooth pattern of the blade. The rpm of the blade is 94rpm using the same motor and gear box that is used on the existing ROC450 system.

Figure 25 750mm Dustless Blade setup and profile

This blade performed in a similar manner to the 950mm dustless blade veering off the spine as the cut progressed down the length of the carcass. As with the larger blade several modification were trialed in an attempt to eliminate this, these included:

- Changes to the holding pressure of fingers to relieve clamping pressure on blade.
- Changes to the robot program to release this pressure on the fingers as the blade travelled through the carcass.

At this point it was acknowledged that the dustless blades were not capable of maintaining a cut down the centre of the spine on the sample goat and ram carcasses. Attention was turned to what could be done to contain the bone and meat dust generated by the toothed blade.

4.6.4 Trials with 720mm diameter toothed blade Mark II

The images below show the modifications that were made to the saw in an attempt to:

- Reduce the amount of bone and meat dust produced
- Contain the dust produced so that it was not sprayed around the workshop
- Guide the saw more asccurately down the centre of the spine.



Figure 26 Modifications made to reduce the production and spread of saw dust

The modifcations to the saw included:

- Guarding around the bottom of the saw blade to collect bone and meat dust.
- Plastic side plates to try to attempt to push the cut meat away from the teeth so that it was not repeatedly cut as the saw moved through the carcass.
- Rollers to guide the blade down the centre of the spine.

Trials with carcasses followed and showed that there was no appreciable reduction in the amount of bone and meat dust produced, however a considerable quantity was captured in the guarding. It is envisaged that if the toothed blade be adopted in practice that guarding such as this would be necessary. The trials also showed that the guide rollers assisted in keeping the saw blade on the centre of the spine.

4.6.5 Trials with 750mm diameter dustless blade Mark 2

Before halting trials at this point and reporting on progress it was decided to retry the 750mm diameter dustless blade again with a few modifications:

1. Reverse the cutting direction of the blade, that is have the blade enter the carcass from the top but have the blade rotating such that from a side view where the carcass is on the right that the blade is rotating in an anticlockwise driection rather than clock wise as has been the case with all previous trials. The thinking here was that the cleaving action of the dustless knife blade may work better if it was ‘pulling’ the carcass against the fingers instead of ‘pushing it against the back plates

2. Modifications to the cut approach for both the vertical and horizontal cuts with a rolling action being used rather than a ‘plunge’ type cut.

3. Modified Carcass retainer. The carcass retainer was lengthened to provide the ability to support the carcass over the entire length.

From trials with these modifications implemeneted good horizontal cuts were achieved with the ‘rolling cutting montion’, indicating that that this blade is suitable for making these horizontal cuts.

Trials for the vertical cut were first conducted with the gripper in its ‘long’ configuration as shown below:

Figure 27 Trials with Blade running in an anti clock wise direction, with Gripper in 'long' configuration

The first cuts showed that with the blade running in the anticlockwise direction, as described above, that the cut down the spine maintined a centralised cut where it was gripped by the top fingers, but moved off the spine between the second and third fingers where the carcass was not supported. The gripper was changed to the ‘short’ format as shown in the below image to test whether the centralised cut could be maintained with the blade rotating in the anticlockwise direction for as long as the carcass was supported by the fingers.

Figure 28 Gripper in 'short' configuration

Unfortunately the results showed that this extra support made no considerable difference, with the blade veering off the spine in a similar position to when the gripper was in its 'long' configuration.

4.6.6 Trial summary and proposed variation to project

In summary from the trials conducted the following was concluded:

- 950mm diameter dustless blade – blade veers off/bends away from the spine leading to soft siding. Struggled to cut horizontal cuts using plunge method. Various modifications with regards to linear cut speeds, finger pressure and cut and approach angle have been trialled but failed to result in a successful split down the centre of the spine.

- 720mm diameter toothed blade – this blade successfully cuts down the centre of the spine and the linear possible cutting speed means that the cycle time is more likely to be achievable. However a large amount of bone and meat dust is produced. Modification were made to the tool in an attempt to reduce and capture this dust, but the reduction achieved was not significant.

- 750mm diameter dustless blade – this is the blade that was originally used in 6 Way cut trials a number of years ago. Similarly to the 950mm diameter blade this veered of the spine. A number of modifications were trialled including blade cutting direction, approach and cutting angle, carcass support from gripper finger positioning. None of these resulted in signifiacnt improvement of the saw tracking down the spine. Good horizontal cuts were achieved with this blade using a rolling type cut.

Hence the results achieved showed that the while the Knife Blade (Dustless Blade) originally proposed is capable of performing the horizontal cuts across the spine of the carcass it is not capable of consistently cutting down the centre of the spine when performing the vertical cut. Trials with the tipped blade showed that, if it is correctly guided, that it cut the carcass down the centre of the spine. Cross carcass cut trials with this tipped blade were also conducted but it was found that too much bone and meat dust were created for this to be considered in a production environment.

The use of the Knife Blade and Tipped Blade was demonstrated to Jon and Josh Hayes from Wodonga Abattoir and Darryl Heidke and Chris Ruberg from MLA on the 16/10/14. Following this demonstration it was agreed that MAR were to develop a proposal that utilised a third robot that would enable the two saw blades to be used to complete the separate cuts.

4.6.7 Variation to project – 3rd Robot and revised layout

The proposed variation was approved in early 2015 and saw the system incorporate a 3rd robot.

Milestone 10a 'Modification to System before shipping to Wodonga, was added to the project which allowed for:

- Purchase of an additional robot
- A new saw, saw blade and robot roll face adaptor

- New robot bag, bag blower, ducting and conduiting
- Robot base and Chem Set fixings
- Gripper modifications
- Saw/guide modifications
- Blade Trials

At this point with the layout above the planned processing of the carcasses was as follows:

- Carcasses enter cell and the vision system takes an image of the carcass to determine cut locations.

- The carcasses leave the infeed conveyor and are ‘grabbed’ by the carcass gripper mounted to the robot on the right hand side in the figure above and moved to the splitting position.

- The splitting saw would split the carcass down the spine. Only the top fingers of the gripper are used during this process so that the saw can be guided down the centre of the carcass by guide rollers fitted to the side of the saw.

- Once split, the carcass gripping robot will close the remaining relevant fingers on the gripper (dependant on the size of the carcass) and move the carcass to the horizontal cut location above the outfeed conveyor. Here the Knife Blade will make the horizontal cuts and the cut pieces will be dropped onto the outfeed conveyor once the cuts are complete.

- Following the completion of the horizontal cuts the leg section will be released to the de gambrel unit (to be supplied by WA) and return to grab the next carcass.

- It was anticipated that the system could run at a rate of 200 carcasses/hr

4.6.8 Carcass Splitting Saw

The images below show the new splitting saw assembly. Features of the design included:

- Spring tensioned guide rollers to hold the carcass central while making the vertical cut. These were upsized following initial trials so that better guidance was achieved.

- Skid plates to prevent the split carcass being dragged in to the mounting following completion of the split.

- Toothed blade profile.

- Mounted on additional robot acquired as part of the project variation

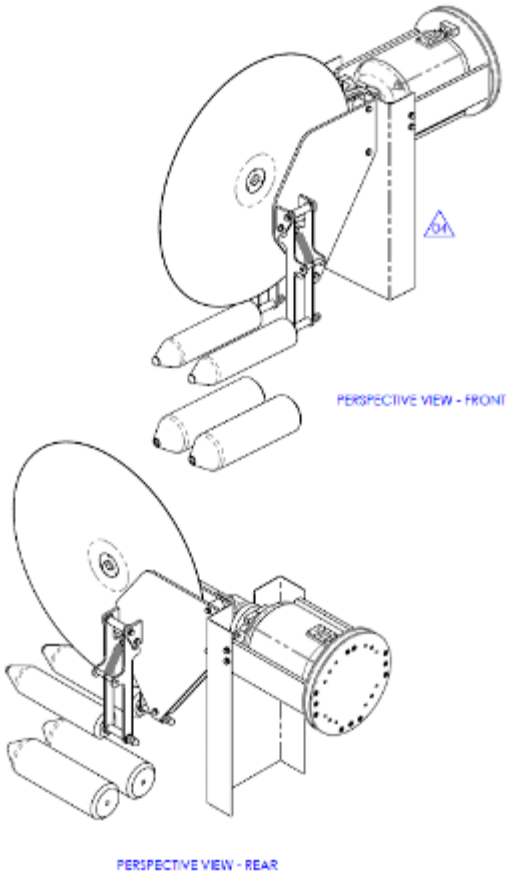


Figure 29 New Splitting saw design

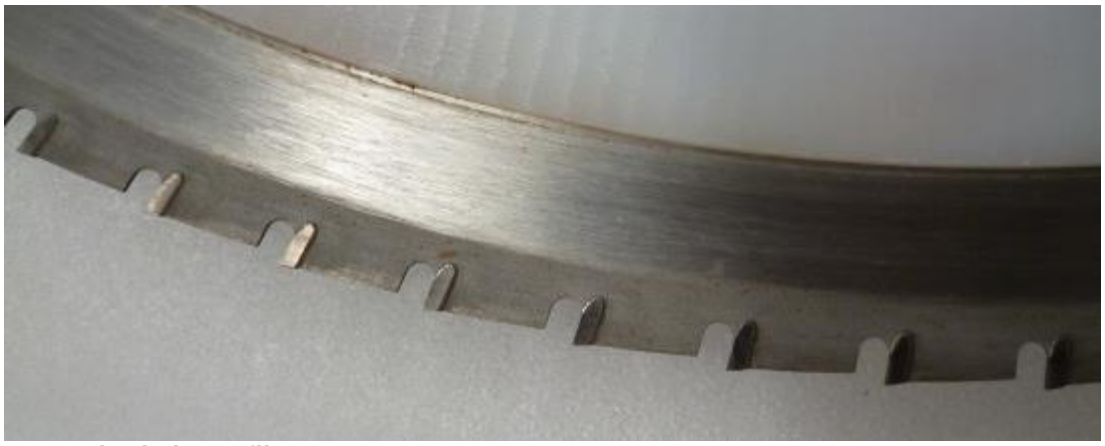


Figure 290 Tooth Blade Profile

4.6.9 Horizontal cutting Saw

The images below show the 750mm diameter Dustless blade chosen for the horizontal carcass cuts. This was chosen in preference to the 950mm diameter blade due to its more aggressive profile. This blade was mounted to the original saw motor and cutting robot.

Figure 31 Horizontal cutting saw blade mounted to the original motor and robot

Figure 302 Blade profile for horizontal cutting saw

4.6.10 Carcass Restrainer Modifications

The gripper was extended in length. These modifications allow the gripper to successfully support the full range of carcasses processed at Wodonga Abattoir.

4.6.11 Trials at MAR with new layout

The image below shows the setup for trials in MAR's workshops in Silverwater.

Figure 313 System setup in MAR's Silverwater workshop

Trials were conducted with the new three robot setup with the cutting paths, algorithms and robot and vision programs being upgraded to suit.
The trials found that the toothed blade was able to successfully split small to large carcasses but revealed the following:

- The saw stalled on extra-large carcasses (>45kg)
- Due to the different profile of goats and rams/sheep a different cutting path was required to successfully split the different species.
- The saw struggled to cut correctly on the larger carcasses, where, due to large chest cavity the hind quarter failed to be correctly gripped by the carcass gripper causing the rump to protrude from the top fingers.

To overcome these issues a number of programming modifications were made to in an attempt to overcome these problems, these included:

- Modifications to the approach and cutting angle of the saw
- Modifications to the vertical cutting speed
- Modifications to the sequencing of the gripper fingers
- Modifications to the sequencing of the gripper pusher plates
- Modifications to the cutting profile to try to accommodate both species with the one program.

None of these modifications successfully resolved the issues being experience and hence saw motor current monitoring and a species selector switch were added to the system. The current monitoring system monitored the motor current of the saw and provided feedback to the robot program. If the feedback showed that the motor current was becoming too high the robot program would react by withdrawing the saw from the cut and allow the saw blade speed to increase again before reinserting to continue with the split of the carcass. The species selector switch was added to the operator panel and selected a different robot program, and hence different cutting path, depending on the species being processed.
In addition, to overcome the issue of the hind quarter protruding from the gripper on larger carcasses it was found that the carcass had to be manually pushed just above the anal canal, using a piece of pipe, into the gripper fingers as it was being gripped. This process highlighted to Wodonga and noted that it would need to be automated once the system was installed on site.

With the current monitoring and selector switch modifications made, the system was able to cut, in the presence of Josh Hayes from Wodonga, the limited number of carcasses that were able to be processed at MAR. It was agreed, in conjunction with Josh that the system needed to get to site and process more product before making any further modifications.

4.7 Installation at Wodonga Abattoirs

The installation of the 6 way cut system was conducted over a three week period during August 2015. MAR worked closely with maintenance staff from Wodonga to achieve the results that are shown below.
A number of modifications were made to the proposed layout shown in Section 4.6.7;

- The automated gambrel pusher required to ensure the hind quarter was fully grabbed by the gripper on larger carcasses was installed at the carcass pick up point.
- The hind leg de-gambrel system was not installed
- The rail was re-routed to leave the cell through the wall opposite the infeed conveyor. Hence the two hind legs exited the cell on the gambrel via this rail.
- A hole was made in the wall into the cutting room to allow the exit of the rail, gambrel and legs. This necessitated the addition of further guarding and another safety mat which required mounting wiring and programming.
- Addition of a blade sterilisation tank for sterilising the blades between species. This required additional wiring and programming.

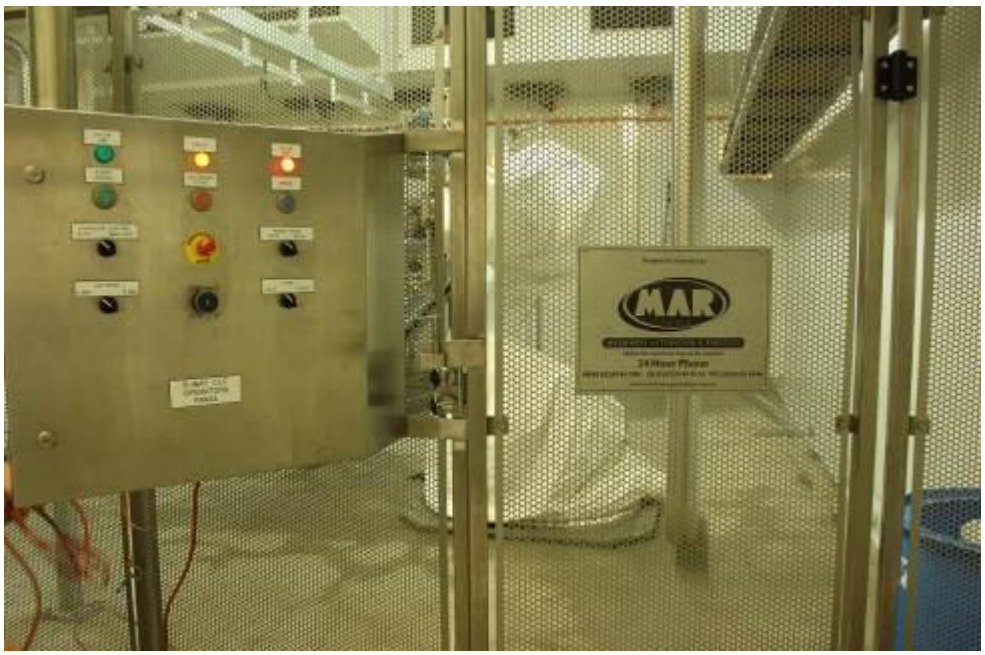


Figure 324 Personnel entrance and operator panel

Figure 335 Carcass entrance

Figure 346 Carcass infeed conveyor with safety mat and carcass gripping robot in the foreground.

Figure 37 The two cutting robots with the carcass camera on the left and product exit conveyor on the right.

Figure 38 Carcass Gripping Robot

Figure 39 Leg exit rail, blade sterilisation tank and product exit conveyor

Figure 40 Additional guarding and safety mat at leg exit

Figure 41 Leg and gambrel exit into cutting room

Figure 352 Product exit chute into cutting room.

4.8 Commissioning at Wodonga Abattoirs

Commissioning of the system followed installaton and the larger quantity of carcasses available (compared to the limited number available in MAR's workshop) allowed for much better analysis of the system. Modifications to the hardware and software were made during the commissioning process allow for the full range of product sizes processed at Wodonga. System ran well with product in the medium to large range with main modifications centred around the processing for the smallest and largest carcasses. The modifications incorporated throughout the commissioning process were:

- Refinment of robot code to suit the different species
- Modification to gripper pushers and robot program to suit the smallest carcasses.
- Modifications to the vertical guides to allow for removal when processing large square backed carcasses where the guides are not necessary and would dig into the carcass.
- As an option to the point above, a selector switch was added so that on very large carcasses the vertical cut could be by passed and only the horizontal cuts performed. The cut primals would then be split in the cutting room on a band saw.
- Modifications to the code and refinments to the set points for the motor current monitoring system
- Addition of a selector switch to vary the position of the cuts depending on carcass leg length. The vision system determines the cut location based on overall carcass length. The lowest point of the carcass was always the tip of the legs and the angle at which the legs hang relative to the body varied depending on whether the carcasses were skin on or skin off. This switch allowed for this variance to be accounted for in the cut location.
- Addition of a screen on the vision system to allow cut positions to be offset with respect to the length of the carcass.

The initial commissioning and training visit of three weeks was conducted during Septembner 2015. MAR then left sight for a period where Wodonga used the system in production. During this period Wodonga produced a punch list of issues which MAR returned to site and addressed. SAT of the system was signed off on 30/10/15. A final visit was made during Novemeber 2015 to address some outstanding issues with the largest carcasses and since this point the system has been running in production with no major issues reported. Videos are attached as Appendicies to this report of the system in operation.

5 Success in Achieving Objectives

Through this project MAR has reviewed the manual 6 Way cutting process at Wodonga Abattoirs. Data on breed, size, weight and cutting accuracies has been gathered, not just on goat (as was originally proposed) but on all species processed. This has allowed the design and development of an automated 6 Way Cutting system that consists of a carcass gripper, carcass splitting saw and horizontal cutting saw. Trials were conducted at MAR's workshops in Sydney which determined there was a need for a third robot which deviated from the original two robot design. This change to a three robot system also saw a change in the expected cycle time. In reality this cycle time is higher than expected due mechanics and programming required to accommodate the range of carcass sizes processed at Wodonga. On medium sized carcasses the system will run at approximately 150 carcasses/hr. The system has been commissioned and is currently running in production at Wodonga Abattoirs.

The video '9604 Final Report Video' attached as Appendix 4 to this report shows the system in operation processing the two extremes of carcasses, skin on goat which are the smallest carcasses processed generally weighing around 15kg or less and a very large ram weighing 78kg. In the video, while cutting the 78kg ram, the current monitoring can be seen taking place. During the cut the saw can be heard to slow, when this occurs the robot withdraws the saw and allows it to speed up again before resuming the cut.

Video '6 Way Cut Device' attached as Appendix 5 to this report, shows the system operating from different perspectives.

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

Using data from the Final Report for Project P.PIP.0387, Ex-Ante CBA for Automated Goat Cutting, prepared by Greenleaf Enterprises, it can be seen that the most significant benefit of the Automated 6 Way cutting system, now, for Wodonga abattoirs is the gain in carcass weight they could achieve by processing the carcasses hot. By not chilling the carcasses, carcass shrink is reduced resulting in a saving per carcass of $0.98. Other benefits are summarised in the figure below and include:

- Increased productivity due to a more consistent supply of product
- Labour savings due to a reduction in band saw operations
- Decreased chilling costs
- Reduction in OH&S costs, by elimination of band saw use and elimination of heavy carcass carrying.

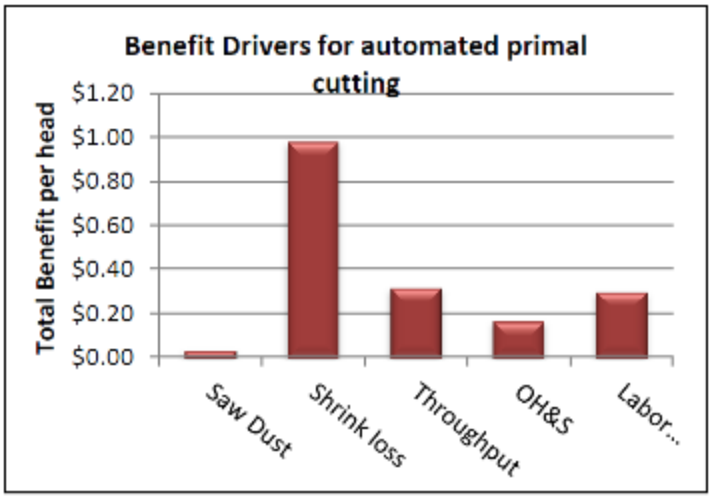


Figure 363 Benefits derived from automated primal cutting

The above benefits would remain true for the Meat and Livestock industry moving forward but this system now also provides the impetus to move forward with a Sheep and Goat cubing development project as highlighted in Section 1 of this report.

7 Conclusions and Recommendations

With the assistance of Wodonga Abattoir this project developed an Automated 6 way Cut System. The original concept of a two robot system, where by a single knife blade, mounted on a robot, split and horizontally cut a goat carcass being held in a gripper mounted on a second robot, had to be modified to a three robot system. Workshop trials concluded that a knife blade was not suitable for splitting goat, sheep or ram carcasses. The trials showed that a toothed saw blade was required to successfully split the harder bones of these carcasses.

The three robot system was installed and commissioned at Wodonga Abattoirs during August – November 2015 and is running successfully in production. The cycle time of the system however is slower than anticipated, processing approximately 150 carcasses/hr. This is due to the mechanical and programming requirements required to accommodate the range of carcasses sizes processed at Wodonga.

Despite this slower than expected cycle time, the benefits of the system for Wodonga from a consistency of product flow and OHS (bandsaw use reduced, heavy carcass lifting reduced) point of view are evident. This combined with the decrease in carcass shrink that could be achieved by reduced chilling means that Wodonga are achieving gains from both a product and personnel point of view as expected from the CBA prepared by Greenleaf.

With this success it is felt that further development in the 6 Way Cut/Sheep and Goat Cubing area would be beneficial to the Australian Meat Industry and it is recommended at further funded projects be pursued in these areas.

8 Appendices

8.1 Appendix 1 – 6 Way Cut Project Charter

8.2 Appendix 2 – 006556 REV 02 6-WAY CUT LAYOUT

8.3 Appendix 3 – 9604-FSM-000-00 - Functional Specification

8.4 Appendix 4 – 9604 Final Report Video

8.5 Appendix 5 – 6 Way Cut Device