final report

Project code: P.PIP.0275

Prepared By: Gavin Inglis
Machinery Automation and Robotics

Date submitted: November 2011

PUBLISHED BY
Meat & Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

ROC 450 Robotic Ovine Cutter System

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

Following the installation of a ROC system at Midfield Meats in Victoria this project was initiated with the aim of increasing the output from the system to 450 carcasses per hour for 2 cuts. The ROC system increases the accuracy of cut and reduces bone dust when compared to a band saw and hence results in increase yield. This coupled with the reduction in OH&S risked due to decreased bandsaw operations and increased output has allowed GM Scott to begin to stream line this boning room operations.

Executive Summary

This project was carried out following the successful implementation of the first ROC system at Midfield Meats in Victoria. The aims of the project were:

- to increase the output of the system to 450 carcasses per hour for 2 cuts
- implement further cuts (up to 4)
- increase yield
- reduce OH&S risk.

The layout of the system was designed to fit in with other modifications occurring in GM Scott's boning room. Increased speed was achieved by the addition of a third robot and further cuts were implemented with redesign of the carcass gripper and modifications to the Vision system algorithms. Speeds in excess of 450 carcasses/hr were achieved for two cuts and yield gains were achieved due to increase in cut accuracy and reduction in bone dust when compared to bandsaw use.
Due to these benefits it is felt that installation of a ROC system would be of great benefit to large numbers of processors both in Australia and around the world and it is recommended that processors consider a ROC system in future expansion plans.

Contents

1 Background

The Robotic Ovine Primal Cutting system replaces manual Bandsaw operations for primal cutting of small stock lamb and sheep processing operations providing flexibility and consistency in cutting dealing with a wide range of carcasses in the Ovine range.

An installed ROC system reduces OH&S risks, the risk of cross-contamination and improves the quality of the cut, reducing sawdust and providing significant yield gains.

In production since 2006, the 1st Robotic Ovine Primal Cutting system developed at Midfield Meat with BMC operated at 200 carcasses per hour, with recent enhancements and introduction of a 2nd robot increasing production rates to approximately 380 per hour.

This system performs a 2 cut operation with leg and shoulder separation only. It utilises vision profiling and dustless blade cutting technology to provided accurate carcass analysis and produces outstanding cutting efficiencies. The Midfield Meat and BMC developed automated Ovine primal cutting system uses equipment from E+V and Freund with Kuka industrial robots, accommodating for size variability.

With the support of MLA, Midfield Meat and BMC, MAR has the licence to commercialise the Robotic Ovine Cutter and to further develop the system and ROC will now be further developed by MAR for integration into more small stock production facilities to operate at faster rates, increased flexibility with improved efficiencies and operational functionality.

2 Project Objectives

This project to further develop the Robotic Ovine Primal Cutter system will provide the following outcomes as described in MAR's proposal 9529Q4-ROC450 for GM SCOTT:

- Manufacture, supply, development, installation and commissioning, of a Robotic Ovine Primal Cutter "ROC" for GM Scott, Cootamundra plant, NSW. (as per MAR Proposal 9529Q4-ROC450 for GM SCOTT)
- Development and trials of key system components as per set milestones.
- ROC system with increased Line Speed and Production Capacity to 450/hr "GM Scott project"
- Provide new functions to analyse and cut new 2 Cut, 3 Cut and 4 Cut specifications
- Provide additional functions to perform two Primal Cut Operations as per GM Scott cut spec (2 per carcass)
- Provide additional functions to perform three Primal Cut Operations as per GM Scott cut spec (3 per carcass)
- Provide additional functions to perform four Primal Cut Operations as per GM Scott cut spec (4 per carcass)
- Change the ROC Robot Technology to an ABB Platform
- New Carcass Gripper Design suitable for cut specifications
- New Carcass Leg Stabilisation Unit suitable for cut specifications
- New System Design Layout and Footprint
- New Control System Design & Interface
- Full documentation including schematics and manuals
- System Videos, reports and documentation detailing the system, its components and operational procedure to be provided for industry dissemination and promotional purpose

Additionally the project aims to achieve a cut accuracy, on all cuts, of as is specified as being achieved in the Green leaf Cost Benefit report at Midfield Meats:

- 98% of cuts within +/- 10mm of the specified location
- 80% of cuts within +/- 6mm of the specified location

3 Methodology

The project will be progressed sequentially through set milestones:

Each milestone must be completed to the satisfaction of MAR, GM Scott and MLA prior to continuation of the project with some milestones having a GO / NO GO decision process attached to them.

Milestone 1 - Initial Design & Project R&D

- Project risk assessment
  MAR will conduct and review with GM Scott 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.

Milestone 2 - Plant Layout and System Design

- Develop component and plant layout design based upon work to date including trials
- Incorporate new features to suit production rates (3 Robots, Conveyors)
- Incorporate new features to suit new cut specifications (Grippers, Leg Gripper, Sensing)
- Incorporate new design into new boning room layout at GM Scott
- Submit a working system design for approval by GM Scott prior to build

Milestone 3 – Major System Components

- Purchasing of robot system components and delivery to MAR to begin system build integrating and programming.
- Robot(s) and controllers
- Carcass handling robot gripper systems

Milestone 4 – System Components for Vision & Cut Trials

- Purchase E+V vision system components
- Manufacture backing boards, frames and lighting
- Purchase Ovine Primal Cutter blade system
- Manufacture Carcass Leg Stabilisation Unit

Milestone 5 – Process Design Review and Benchmarking

- MAR will work with GM Scott and BMC 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 for Woolworths 2 cut specification
- Performance and accuracy review of current manual bandsaw primal cut operations for Woolworths optional 3 cut specification
- Performance and accuracy review of current manual bandsaw primal cut operations for Bush's 4 cut specification
- Document current cut accuracies, yield performance and process data

Milestone 6 – Sensing & Cut Specification Trials & Development

- Use of E+V sensing system setup at Midfield Meat for Trials
- Software development with new algorithms to suit cut specifications
- Collect and analyse vision acquisition data to suit GM Scott "Woolworths 2 cut specification"
- Collect and analyse vision acquisition data to suit GM Scott "Woolworths 3 cut specification"
- Collect and analyse vision acquisition data to suit GM Scott "Bush's 4 cut specification"
- Document accuracies determined from trials

Milestone 7 - Carcass Handling, Gripper Development & Trials

- Design & Review Current Carcass Handling (gripper system)
- Design new gripper system to suit GM Scott cut specifications
- Manufacture of new Carcass Handling Gripper System for Trials at MAR
- Functional Test of gripper equipment
- Conduct carcass handling gripper trials at MAR with new gripper

Milestone 8 – Cut Specification & Cycle Time Trials

- Setup E+V vision and backing board systems at MAR
- Setup Primal Cut Blade onto robot system at MAR
- Setup carcass gripper and robot system at MAR
- Functional test of grippers, saw, robots and vision system.
- Perform Vision and Cut Cycle trails at MAR
- Document Trails to confirm design suitable for cut specifications and production rates

Milestone 9 – Control System and Sensing Components

- Purchasing of control system and sensing components and delivery to MAR to begin system build integrating and programming.
- Purchase sensing and equipment
- Control Systems, Switch Gear, Panels, PLC, PC systems

Milestone 10 – System Components

- Purchasing of system components and delivery to MAR to begin system build integrating and programming.
- Robot Base Frames, protective covers
- Tool Cleaning System
- Primal Exit & O/H Rail Conveyor Auxiliary Components
- Safety System, controls, floor mats and fencing components

Milestone 11 – System Build & Programming

- System Build & Installation at MAR for purpose of FAT
- Initial offline programming of robot, HMI, PLC & control system interfacing
- Program and develop ABB co-ordinated 3 robot system for ROC

Milestone 12 – System Setup

- Mechanical & Electrical Setup & Test of System
- Test tooling robotic operated
- Setup & Test safety systems
- Trial ands Commission ABB co-ordinated 3 robot system for ROC
- Integrate Sensing System(s)
- Component Integration R&D

Milestone 13 – System Testing & Trials

- Trial and troubleshoot of system
- Setup and test manual and semi auto operations
- Setup and test full auto cycle operations of system

Milestone 14 - System FAT at MAR

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

Milestone 15 – Site Preparation for installation (Supplied by GM Scott)

- Prepare site for installation of ROC system
- Building preparation including internal wall modifications
- Relocation of existing conveyors equipment
- O/H rail conveyor system installation to suit ROC System
- Primal Cut Exit conveyor systems (included in new boning room)
- Preparation of Services (water, power, etc)

Milestone 16 - On-Site Staged Installation of System

- Equipment Transport to Site
- Installation of robot(s), safety and auxiliary systems
- Installation of sensing, tool cleaning and controls
- Electrical and services installation

Milestone 17 – System Setup Testing & Trials

- Mechanical & Electrical Setup & Test of System
- Setup & Test safety systems
- Test tooling robotic operated
- Setup and test manual and semi auto operations
- Setup and test full auto cycle operations of system

Milestone 18 – System Commissioning and Production Trials

- Commission ROC system
- Production trials of system
- Production and cycle time trials
- Site support & Operator Training

Milestone 19 - 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

4 Results and Discussion

4.1 Initial site visit and System Layout Design

The MAR project commenced with a visit to GM Scott site. During and following this visit several locations for the ROC 450 system were considered. GM Scott had decided not to fully upgrade the boning room as had been proposed during the quotation phase of the project and hence options other than what had been suggested in MAR's proposal were discussed. The final location decided upon is shown in the image below.

Fig.1 Image showing location of Robot cell prior to installation

The layout out of the cell went through several iterations to accommodate other modifications in the room before the layout below was settled upon.

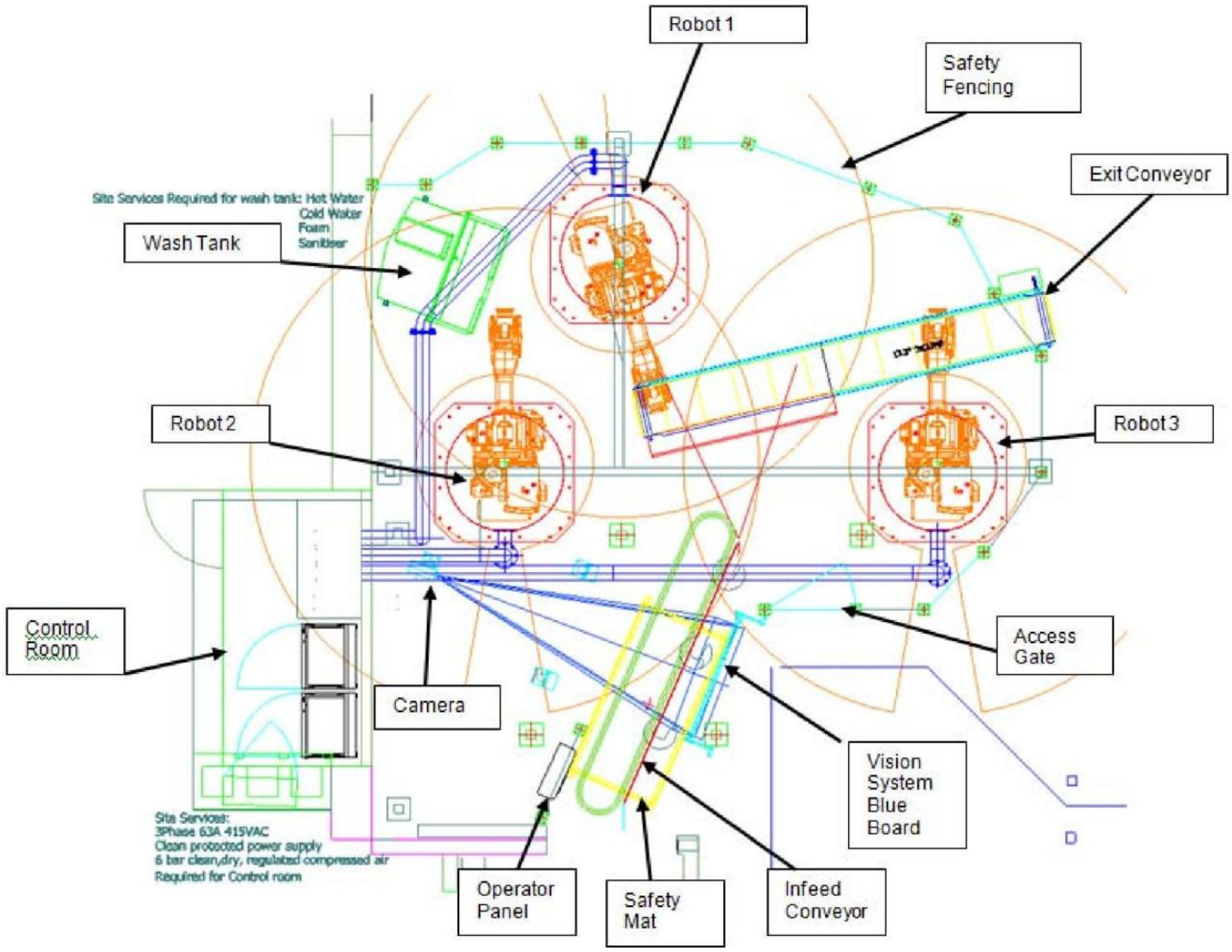


Fig.2 Layout of ROC 450 System at GM Scott

As can be seen from the layout the system consists of the following main items:

- Three robots, two carcass gripping robots and one carcass cutting robot
- Infeed and exit conveyors (supplied by GM Scott)
- Carcass grippers and cutting blade
- Vision system
- Safety fencing
- Entry Safety mat
- Blade wash tank
- Operator control panel

The layout shows the control room which houses the robot controls, Main Control Cabinet and the Vision system computer and screen. The blue conduits from each robot to the Control Room carry the robot cables back to the controllers.

4.2 Robots

The robots are ABB IRB6640's with a 205kg payload and 2.75 m reach capability. Two robots are fitted with Carcass grippers while the third is fitted with the cutting saw motor and blade. Each of the robots is covered with a white protective bag custom made from flexible material designed to fit the robot and protect it during wash down conditions.

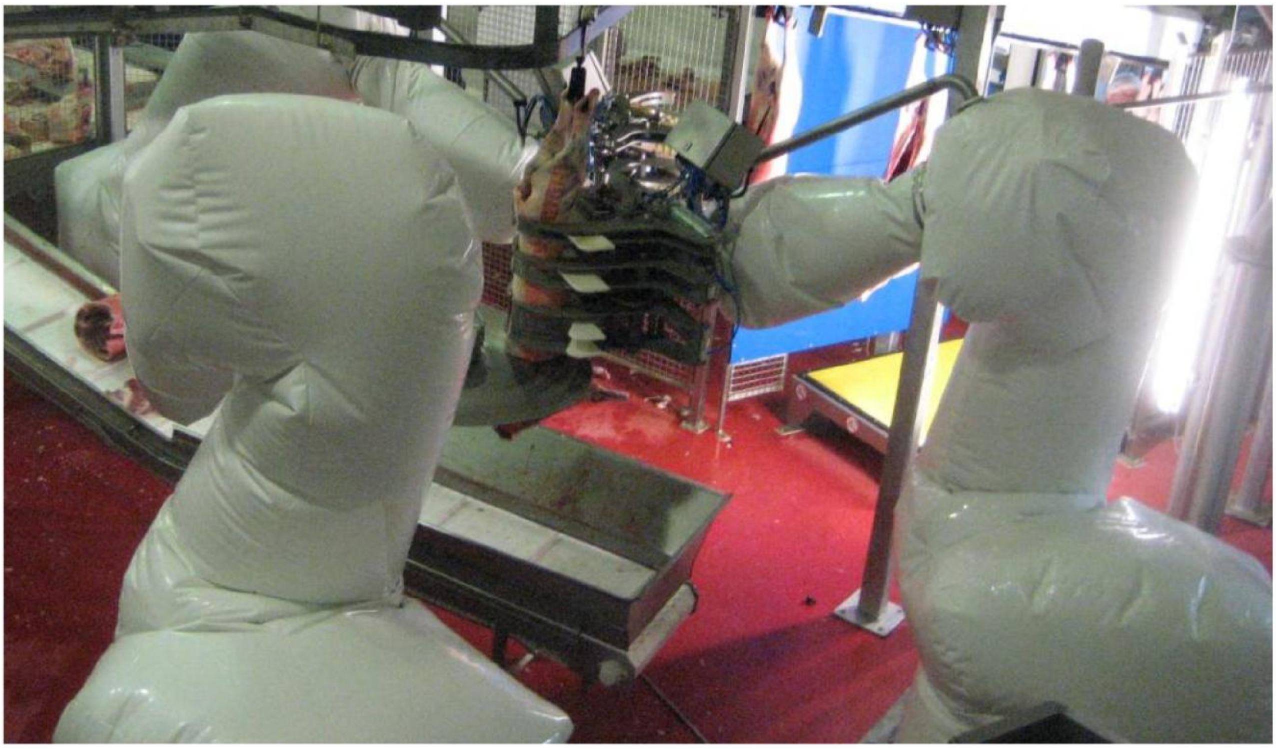


Fig.3 Robots on site at GM Scott

4.3 Cut specification and ensuing gripper design

The images below show the three different configurations of cut specification required by GM Scott.

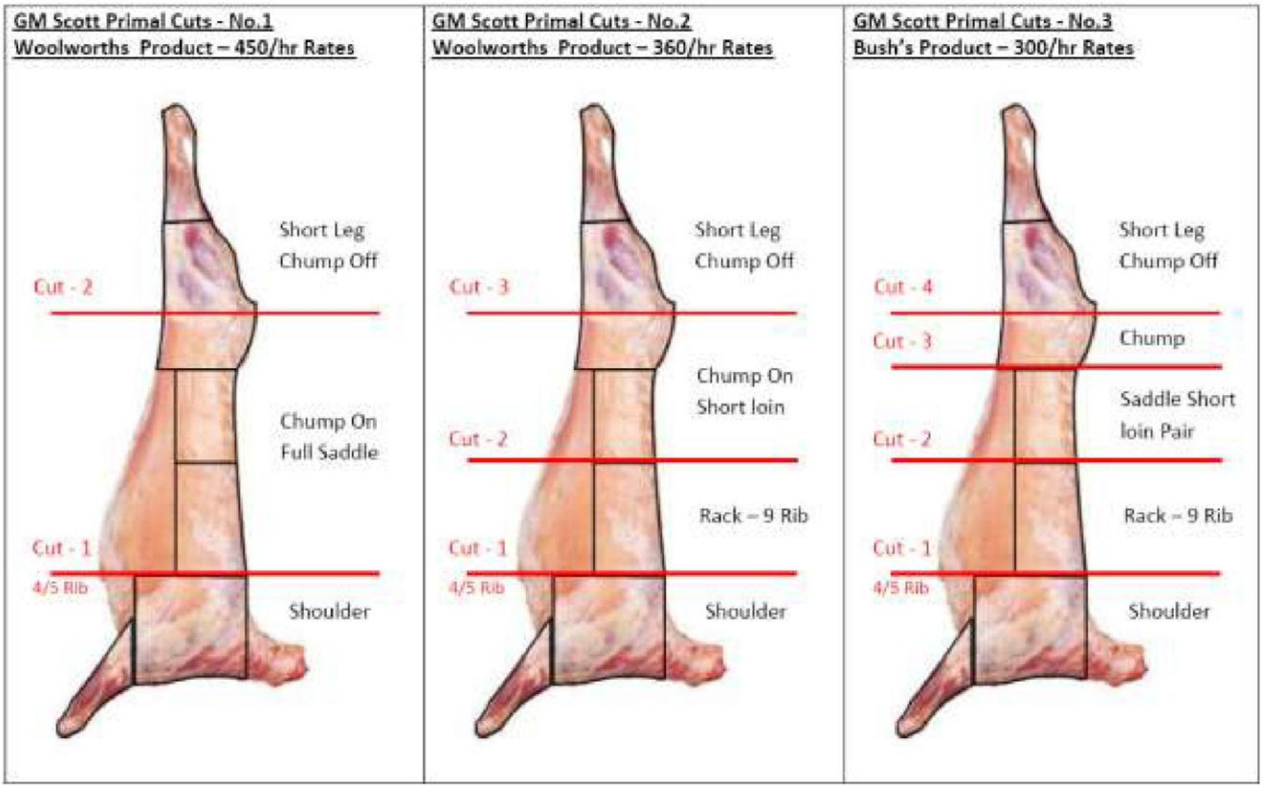


Fig.4 Cut specifications

The cuts are defined in the following manner:

4.3.1 Primal Cut Number 1

2 off Primal Cuts for Woolworths Product – 450/hr Rates
Producing 3 Primal Cuts

- Shoulder
- Chump On Full Saddle
- Short Leg Chump Off

4.3.2 Primal Cut Number 2

3 off Primal Cuts for Woolworths Product – 350/hr Rates
Producing 4 Primal Cuts

- Shoulder
- Rack 9 Rib

- Chump On Short Loin
- Short Leg Chump Off

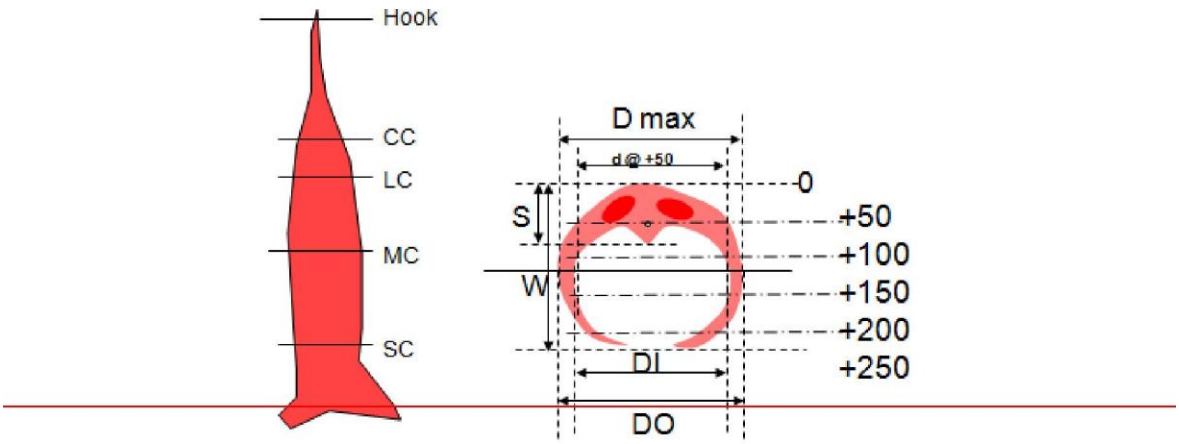
4.3.3 Primal Cut Number 3

4 off Primal Cuts for Bush's Product – 300/hr Rates

Producing 5 Primal Cuts

- Shoulder
- Rack 9 Rib
- Saddle Short Loin Pair
- Chump
- Short Leg Chump Off

These cuts define how the gripper was to be designed and during a subsequent visit to GM Scott measurements were taken of a selection of carcasses between the largest and smallest carcasses that were to be processed to enable this design process to take place. The figure below shows the measurements that were taken.



MAR-MLA GM Scott Measurements 25-26 Aug 2010											d @	d @	d @	d @	d @	W	
	Wgt-Kg	L	SC	MC	LC	CC	D max		DI	DO	+50	+100	+150	+200	+250	MAX	S
A	14.3	950	805	570	410	330	230	SC	120	160	180	150	125	0	0	250	83
								MC	180	230	250	0	0	0	0	190	50
B	15.8	950	800	590	415	330	215	SC	110	160	145	170	160	130	95	270	90
								MC	200	235	170	230	240	185	0	210	53
C	22.7	1110	935	685	469	380	230	SC	120	180	130	185	175	155	100	300	100
								MC	210	250	230	250	220	0	0	250	60
D	23.4	1170	960	700	505	415	255	SC	140	200	140	205	195	180	150	290	110
								MC	230	270	185	170	250	0	0	230	60

Fig.5 Onsite carcass measurements for gripper design

The cut specification and these measurements specified that the gripper was to have 3 sets of fingers for attachment and fixation of the chump, the short lion and rack barrel sections

The concept for the gripper was to be based on the gripper used at Midfield Meats, but with better precision and direct drive actuation avoiding gear coupling. The gripper designed is shown below. The gripper fingers pneumatically operated and designed to wrap around the carcass while the pneumatic carcass pushers secure the carcass to prevent movement during cutting.

4.4 Cutting Blade

The cutting blade and saw replicated what was used at Midfield Meats. It utilised a Freund motor and dustless blade. Mounting plates to support the saw motor and prevent movement of the blade during operation were fabricated and integrated into the roll face adaptor at MAR.
The dustless blade allows very clean cutting of the carcasses producing minimal bone dust and dramatically increasing the shelf life of the meat.

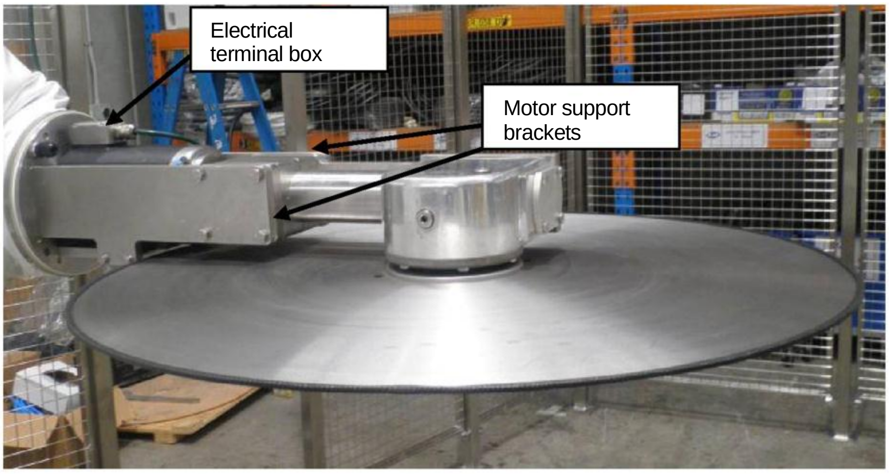


Fig.4 Motor and blade mounted to robot

Fig.5 The cutting edge of the blade

4.5 Vision System

The system uses an E+V Vision System to determine the carcass cut positions. An image of each carcass is taken as the carcass passes in front of the camera with the blue board as back ground. Cut data from the camera system is transferred to the robot system by RS232. The vision system itself consists of a camera, PC and Screen (located in the control room), two high frequency fluorescent lights each with two tubes, a blue backing board and an image trigger switch. An image of the system is shown below:

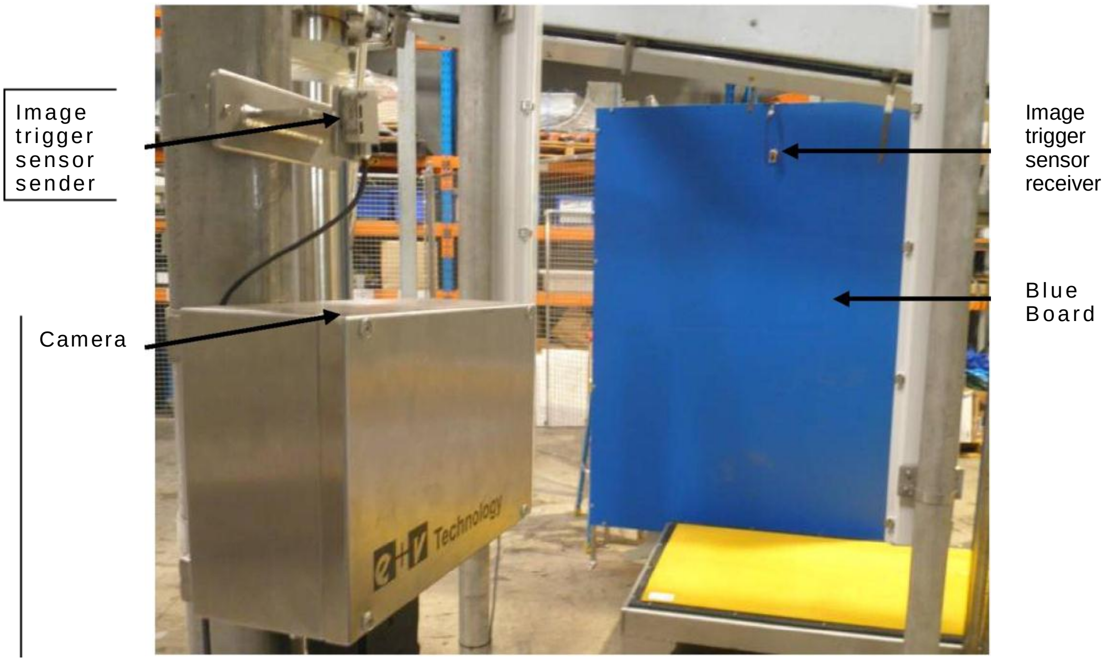


Figure 6: Vision System Setup

The image received on the screen in the control room is shown below along with the operator interface which allows the operator to select the cuts required and enter any cut offsets necessary. The cuts are selected but checking or de checking the check boxes along side the cut name. The system is set up so that at no point is the operator able to deselect both the Chump Cut and Leg Cut, doing this would cause the gripper to rip the remaining potion of the carcass from the rail as it went to deposit the primal cuts onto the out going conveyor. The offsets are used by the operator to tune the position of the cuts during operation. Decreasing a positive number or making a negative number more negative will raise the height of the cut, increasing a positive number or moving a negative number more towards zero will lower height of the cut.

4.6 Safety Fencing and Safety Mat

The image below shows the safety fencing installed around the cell. The fencing is constructed of 40mm x 40mm stainless steel mesh. There is an access gate adjacent to the vision system blue board that is fitted with a Fortress Key system (shown in Fig. 15) that only allows access to the cell once the system is in an emergency stop situation, ie all power is removed from the robots and conveyors and no movement is possible in automatic mode.

Figure 7: Cell Fencing

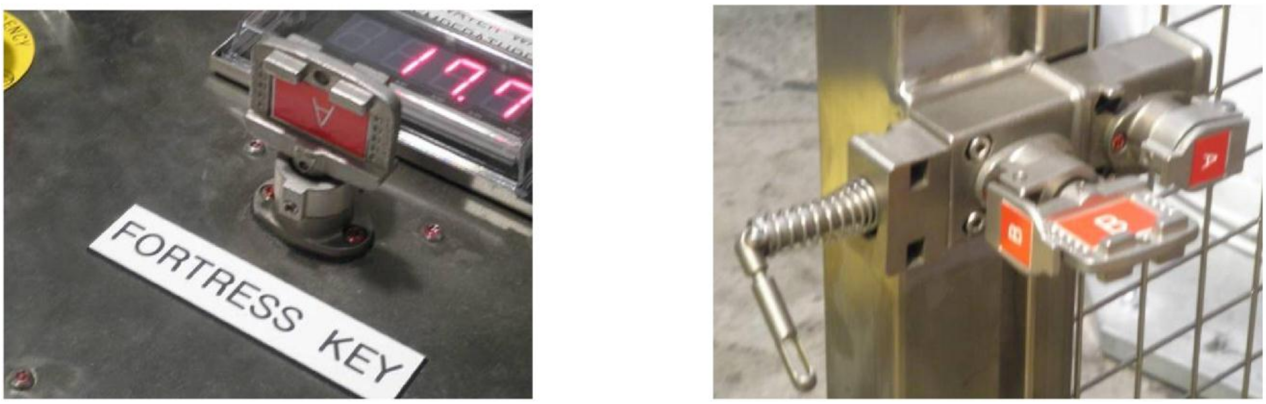


Figure 8: Fortress Key System

A pressure sensitive mat has been used at the carcass entrance to the cell to prevent a person from entering the cell while the robots are running. The mat is monitored by a safety relay which detects if a weight is placed on the mat and drops out the auto stop contactors immediately stopping the movement of the robots and conveyor systems if this occurs.

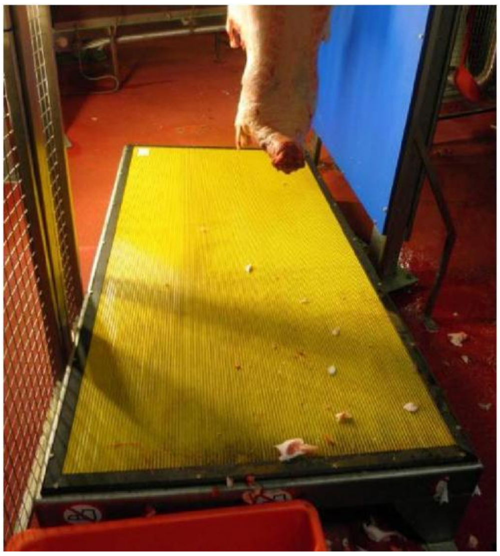


Fig. 9 Safety mat at carcass entry point

4.7 Blade Wash Tank

The blade wash tank design was similar to that used at Midfield, however for ease of robot programming the tank was positioned in a more horizontal position as shown in Fig. 17 below. Fig. 18 below shows the nozzle configuration inside the tank, this is currently being modified to improve the effectiveness of the wash.

Fig. 10 Blade wash tank

Fig.11 Wash tank nozzle configuration

4.8 Infeed and out feed conveyors

The infeed and outfeed conveyors shown in the figures below were supplied by GM Scott. The figures show the inclined infeed conveyor that brings the carcasses from the chiller to the carcass/ gripper pick up point, the primal exit conveyor and the leg exit conveyor including the cylinder that has been installed to drag the legs from robot 2 around the corner and down the decline.

Fig. 12 Inclined carcass infeed conveyor

Fig. 13 Primal exit and leg exit conveyors

Fig.14 Leg Exit conveyor

4.9 Operator Panel

The operator panel shown below is located at the carcass entry point to the system. The operator panel allows the operator full control of the system and allows maintenance to put the system into maintenance mode when required.

Fig.15 System Operator Panel

5 Success in Achieving Objectives

As can be seen from the details provided in the above section the objectives for the project were achieved. Specifically

1. A Robotic Ovine Primal Cutter 'ROC' system was developed, manufactured, supplied installed, commissioned and is currently being used in production at GM Scott, Cootamundra plant, NSW as per MAR Proposal 9529Q4-ROC450.

2. Development and trials of key system components were carried out at MAR's workshop in Silverwater NSW and at GM Scott as per set milestones.

3. A ROC system with increased Line Speed and Production Capacity of 450/hr for 2 cuts was achieved. In fact the actually achieved are as follows:
   - 2 cuts – 496 carcasses/hr
   - 3 cuts – 411 carcasses/hr
   - 4 cuts - 383 carcasses/hr

4. As can be seen in Section 4.5 above new functions have been provided to:
   - analyse and cut new 2 Cut, 3 Cut and 4 Cut specifications
   - perform two Primal Cut Operations as per GM Scott cut spec (2 per carcass)
   - perform three Primal Cut Operations as per GM Scott cut spec (3 per carcass)
   - perform four Primal Cut Operations as per GM Scott cut spec (4 per carcass)

5. As can be seen from section 4.2 above the robots used were three ABB IRB 6640 robots with IRC5 controllers
6. Section 4.3 above describes the design and manufacture of new carcass grippers, additional leg stabilisation was not required due to this new design.
7. Section 4.1 above shows that a new system layout was designed so that it incorporated three robots and infeed and out feed conveyors that met the requirements of GM Scott's site.
8. Sections 4.5 and 4.9 above show the new Operator interface. Behind this a new control system has been designed to interface these controls with the Vision System and ABB robot platform.
9. Full documentation both in hard and soft copy format have been supplied to GM Scott.

10. System Videos, reports and documentation detailing the system and its components form the subject of this report and accompanying videos.

11. From analysis conducted on 41 carcasses in conjunction with GM Scott's Head of QA on 28/10/11 the following results were achieved:

Cut	Within +/- 6mm or 4 ribs	Within +/- 10mm or 0.5 ribs	Outside +/- 10mm or 0.5 ribs
Shoulder Cut	80.5 %	17.1%	2.4%
Middle Cut	95.1%	4.9%	0%
Leg Cut	100%	0%	0%
Chump Cut	100%	0%	0%

It can be seen from these results that the criteria was met for the Middle Cut, Leg Cut and Chump Cut. The Shoulder cut achieved and accuracy of 97.6% within +/- 10mm (98% specified). Discussions were held with GM Scott QA and it was agreed that the 1 carcass out of the 41 analysed that had the shoulder cut out by more than 10mm was a particularly large carcass and probably out of the 'normal' weight range for what is processed at GM Scott. It was agreed that this would be monitored for the following month and if there continued to be issues refinement to the algorithms in the vision system would be made. On the date of writing this report it is over 5 weeks since the analysis was performed and no further issues have been reported.

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

From the information presented above it can be seen that based on the results achieved by the ROC 450 system installed at GM Scott in Cootamundra this system can have significant impact on the Meat and Livestock industry both now and over the next 5 years.

1) Based on analysis done on manually (bandsaw) cut shoulder cuts at GM Scott during the installation of the ROC system the accuracy achieved for 4 ribs was only 65%. Hence it can be seen immediately that there is a 15.5% increase in this cut resulting in yield benefits.

2) At the current speed of 383 carcasses /hour at 4 cuts the boning room struggles to keep up with the production rate. With further refinement and tuning of the system it is anticipated that speeds of 600 carcasses/hour could be achieved for 3 cuts.

3) The knife blade used in this application creates much less bone dust than the blade of a band saw. This not only increases the yield but also improves the shelf life of the meat.

4) Use of the robot eliminates up to 4 bandsaw cuts that would other wise have to be made by a bandsaw operator. Elimination of these cuts has obvious OH&S benefits.

7 Conclusions and Recommendations

From the results achieved through implementation of the ROC 450 system at GM Scott in Cootamundra, it can be seen that there are not only the obvious OH&S benefits from eliminating the use of band saws but also improvements in cut accuracy ,and hence yield, speed of operation and shelf life of the product.
Hence it is felt that installation of a ROC system would be of great benefit to large numbers of processors both in Australia and around the world. It is recommended that processors consider a ROC system in future expansion plans.