final report

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Automatic tool for robotic evisceration – Proof of concept

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Abstract

The objectives of this project are to design and trial a tool capable of successfully eviscerating lamb, sheep and mutton carcases using a standard robot. This must be done such that the tool is low cost but also meets user requirements in speed, cleaning and sanitisation. At the completion of successful tool development and trial the project should detail the next steps in proof of concept, implementation and commercialisation.

The body of this report will show the iterative development of a tool that successfully eviscerates the required carcases and recommends a plan for the next steps for the development and commercialisation of this system.

Executive Summary

During site visits conducted in a BMC Auto Evisceration Study completed in 2008 all consulted consider the current manual Lamb Evisceration process as important and urgent to automate as the task is highly arduous, ergonomically unfriendly and generally unpleasant. These findings were also supported by MAR who reviewed Evisceration automation possibilities with MLA, visiting processing sites around Australia. An automated solution at the right price would also bring savings, but more importantly, consistency in throughput.

In line with steps included in the BMC study, this project is to make a strategic advance to prove the most critical aspect of the solution, that being the EV tool.

As will be seen throughout the body of this report an iterative process of tool design accompanied by site trials has developed a tool that is suitable for robot mounting, successful evisceration of carcases in the weight range of 15 – 30 kg and application in plants with a line speed >10 carcases/ min.

The benefits to be achieved by utilisation and continued development of an Automatic Tool for Robotic Evisceration include:

- Improvements in OH&S;
  - Elimination of risk of operator strain injury from the size, weight and repetitive tasking
  - Elimination of dangerous operational practices
- Consistency;
  - Robotic mounting and control of the evisceration process improves accuracy and repeatability over manual removal systems
- Improved yield through;
  - Improved yield payback by ensuring the carcases are more consistently eviscerated prior to weighing
  - flexibility of the system to change path specifications upon requests
- Labour cost:
  - The system will replace 1 unit of labour per shift.
- Line Speed:
  - The system can operate at line speed >10 carcases/min.
- Species:
  - The Automatic Evisceration System is suitable for use in lamb, sheep and mutton

Reliability and accuracy, along with processing speed which are critical to the success and acceptance of this technology have been proven in this project.

Contents

1 Background

During a BMC Auto Evisceration Study supported by AMPC and MLA and completed in 2008, several lamb slaughter lines were visited and the evisceration process observed. In discussion, all consulted consider the current manual process important and urgent to automate as the task is highly arduous, ergonomically unfriendly and generally unpleasant. An automated solution at the right price would also bring savings, but more importantly, consistency in throughput.
In line with steps included in the BMC study, this project is to make a strategic advance to prove the most critical aspect of the solution, that being the EV tool.

2 Project Objectives

The objectives of this project are as follows:

a) To design, implement, test and prove functionality of the proposed evisceration tool capable of operation with a standard robot for the removal of viscera and offal in one cycle compatible with in-line operation
b) To reach a design status that allows practical implementation of the tool at the lowest cost allowing for functional characteristics that meets user requirements in speed, cleaning and sanitisation, reliability and ease of integration with a robot.
c) To detail further the next steps in the proof of concept implementation and commercialisation based on the findings of this part of the project.

3 Methodology

The project is divided up into the following tasks. Previously submitted Milestone reports have described the completed Tasks 1,2 and 3 (Milestone Report 1) and Tasks 4 and 5 (Milestone Report 2). This final report will describe the completion of Tasks 5 – 10.

Task 1: Detailed assessment of the literature for designs and concepts for automatic evisceration where the tool may be used with modifications to remove the viscera and offal in one pass (this is to ensure that the novelty in the proposed tool is retained by the project).

Task 2: Definition of system design for the proof of concept of the EV tool. This design is to include the required temporary handling system as well as the robot in a temporary cell or location to be used with the EV tool for trials in as suitable environment also accommodating for safety.

Task 3: Definition of the desired tools and prototyping using mock ups to reach practical realisation of the required design features for the First Prototype EV Tool.

Task 4: Detailed design and construction of EV Tool for use with any standard robot. The design to include passive compliance features for adaptation in path whilst it traverses the inside of the spine (i.e. self aligning using compliance rather than in active servo control).

Task 5: Assessment of path variability in carcases and definition of robot programs with user input that allow carcases of variable profile to be eviscerated without the use of sensors

Task 6: Acquisition of all necessary equipment (on a rental basis) including design and build of temporary mechanisms for holding carcases in a static robot cell.

Task 7: Installation and integration of the trial cell with robot and tool set up for trials with carcases.

Task 8: Perform trials with 50 conforming carcases (not damage or deformed, etc) and observation of performance.

Task 9: Assessment of status and iterative improvements if needed until speed and operational features are proved to be functional and reliable. Refinements in design and test system hardware or software may be required with tests repeated to reach a final results proving the EV tool.

Task 10: Final demonstration of the tool and presentation of final report

4 Results and Discussion

4.1 Tool Development and Results of Literature Review

Initial concepts for the evisceration tool design were presented in the project application and depicted a plough or shovel like tool as shown in Fig.1 below

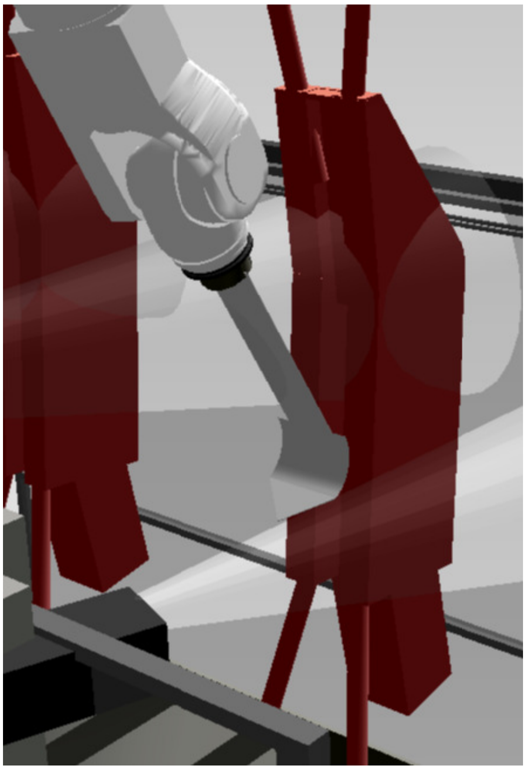

Fig. 1 Initial Concept tool

Following the commencement of collaborative work between MAR and BMC on this project the literature review conducted in Task 1 revealed that a plough shaped tool was used in existing Automated Evisceration solutions for pig and lamb slaughter lines where there is significant uniformity in carcase size and shape. The challenge in the Australian meat industry however, is that the development of any tool will require consideration of a wider variability in carcase size and shape. With this in mind several concepts from a simple passive tool to a powered tool were considered and trialled. These are shown below In Figure 2.

Fig. 2 Preliminary passive and powered tools trialled

The first tool trialled was a blunt edge plate with a handle where the plate has a rounded V profile at the end such shaped to follow the spine on the inside of the lamb carcase.

Trials reveal that significant forces are required to cut through the connective tissues between the viscera and the spine and also the tool could not perform separation at the diaphragm to reach the organs. The tool was sharpened at the leading edge on the face away from the spine and even with this feature the tool required significant force to drive through the connective tissues, the diaphragm and complete the organ separation. In addition to damage caused to the organs, the tool would not pass through the breast and neck gaps inside the carcase cavity to complete the separation.
The second tool provided a powered set of reciprocation blades, where this provided the possibility for the tool to travel along the spine separating the viscera and organs as well as the connective tissues, with much lower forces than that needed by Tool A. This provided a better mechanism for separation but needed greater path control when following the spine. The problem of separation through the breast and neck cavity was observed leading to the modification of this tool to the next version, shown below.

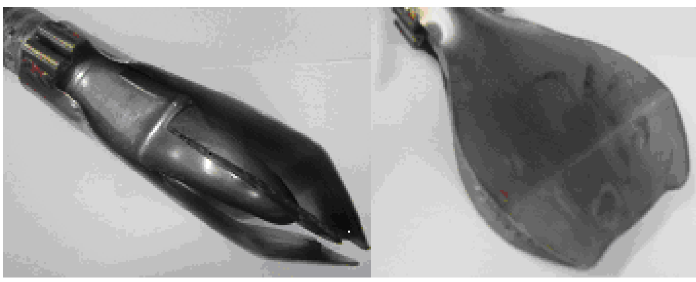

Fig. 3 Reciprocating Blade Tool

The profile of the tool allows the powered tool to follow the profile of the spine, whilst pressing on top of the viscera and the organs releasing them from the carcase. Two problems where encountered:

1. The tool would not provide adequate separation at the diaphragm
2. The tool did not clear the breast and neck cavity despite the slimmer width and the profile to push open the carcase for exit.

The course of action in the project was then to review the process and consider a new concept.
The following was decided:

In the complete process for bung dropping to evisceration and then inspection the steps may be as follows:

i) Bung drop, tie the bung (optional) and push the bung into the body of the carcase – which may be automated using MAR technology,
ii) Belly open and brisket cut full allowing the viscera to drop out, but still attached ,
iii) Tie the bung (if not already done) manually and separate at the connective tissues form the spine, whilst making the diaphragm cuts to the sides of the viscera. At this stage the carcase is fully open in the front and the viscera, with the organs are still attached.
iv) Use new EV tool to engage the carcase just above the diaphragm and start the process of viscera and organ removal in one pass.

An assessment of the cycle for each step suggests that each may be performed in a 5 second cycle with the carcase on the move; however, the EV tool requires testing before the work on cycle assessment of step (iv) can begin.

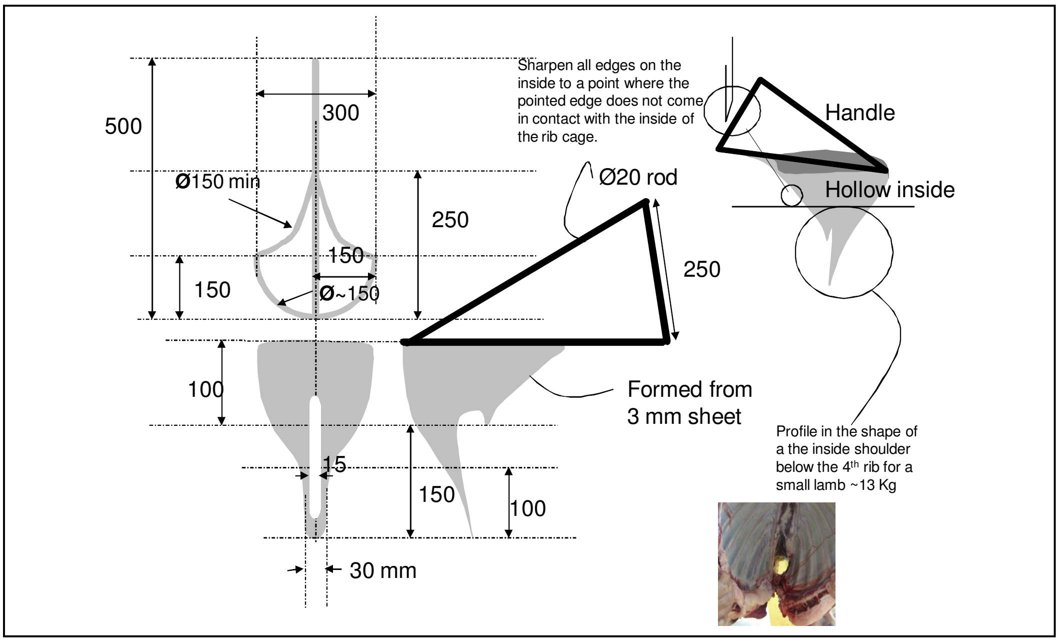

Fig.4 Preliminary Design for Automated tool

Fig.4 above shows the concept and outline design for the tool that was tested and considered to be the correct tool for performing the task of viscera and organ separation from the carcase in the way envisaged. This tool underwent several iterative modifications followed by manual testing to optimise the design based on practical trials. The images below show the design that was successfully manually tested at Midfield in Warrnambool. A fork shape conic tip profile was introduced to guide the tool along the spine whilst covering the inside of the breast and penetrating the neck cavity. This would overcome the limitation of all the other tools tested.

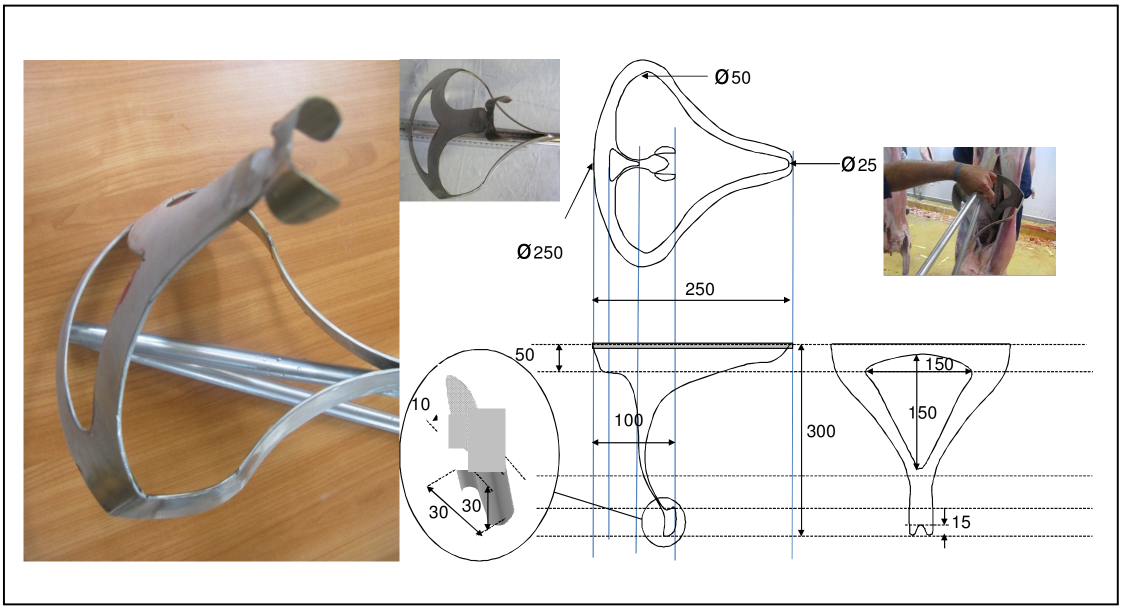

Fig.5 Fabricated tool for manual trials

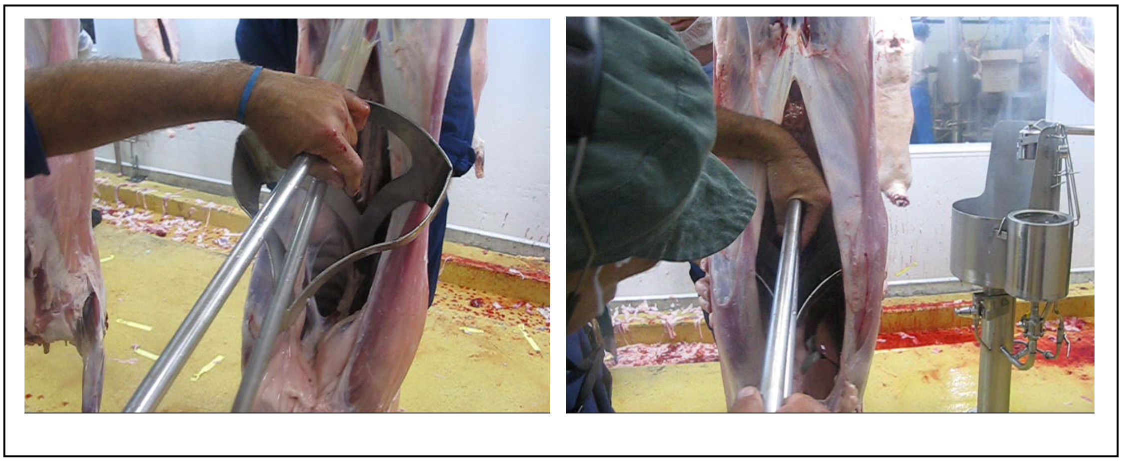

Fig. 6 Manual Trials

4.2 System layout for proof of concept of the EV tool

Figure 7 below shows the arrangement to be used for trials and proof of concept of the EV tool.

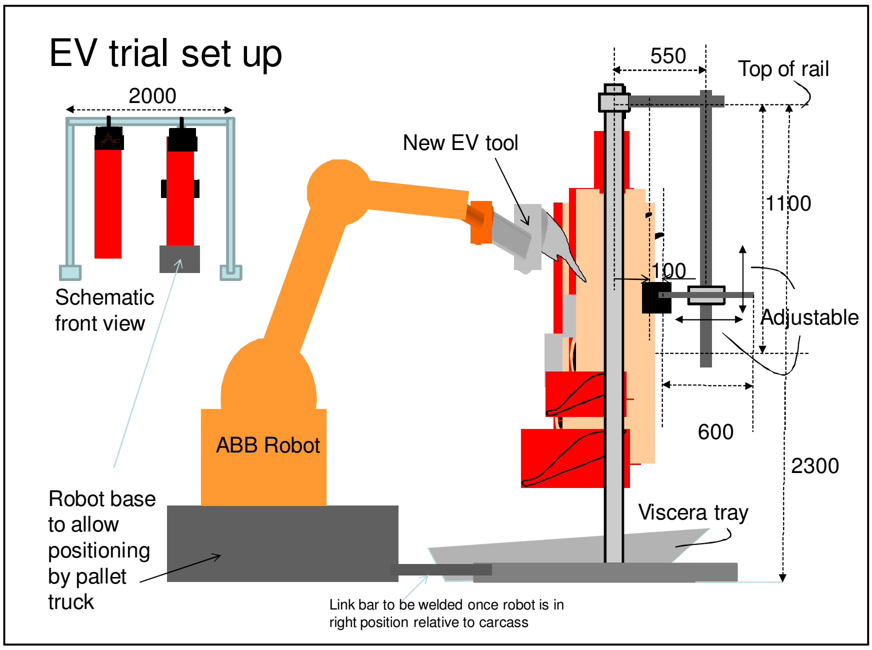

Fig.7 Planned setup of robot and carcase support stand for trials

4.3 Steps required for new Robotic Evisceration Process

Although the current tool proof of concept project will be conducted on stationary carcases the figure below illustrates one option for steps of a fully automated evisceration process.
The process for automation would require:

- At position A the carcase enters the evisceration area with the brisket pre-cut
- Manual action at B where an incision is made and belly opened to prepare the bung "bagged or clipped".
- From C to D a robot is used with the EV Tool attached to separate the viscera and the offal in one pass

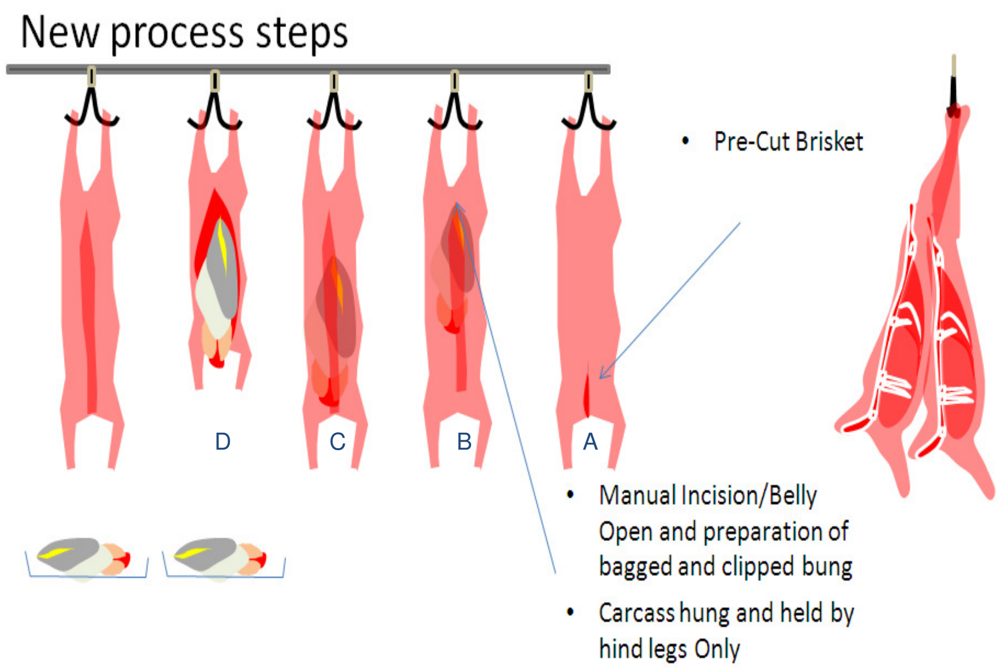

Fig. 8 Planned setup of robot and carcase support stand for trials

4.4 Robot Program Path

The path the robot needs to follow using the tool designed above is along the profile of the spine, and whilst maintaining contact with the inside of the carcase the tool needs to go through orientation changes as it is moved down the carcase. The expected tool positions are illustrated in Figure 9 from left to right.

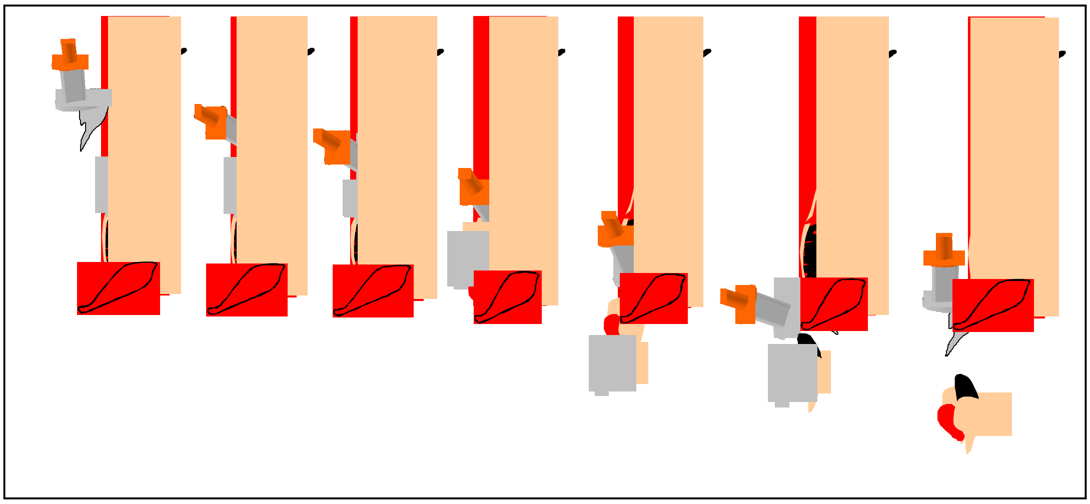

Fig.9 Planned robot path

4.5 Onsite trials and iterative tool improvements

Following modification to the manual tool to allow mounting on the roll face of a robot, initial trials were conducted at MAR's workshops in Silverwater. The carcases used were killed at Peel Valley in Tamworth and then driven down to Sydney. Since these carcases were not 'hot' when they arrived at MAR they did not prove to be ideal carcases to trial. We are able to establish however that the 'nose' of the tool needed modification since the sharp edges of the existing nose damaged the inside of the carcase and we did successfully eviscerate one of the six carcases and the video of this is shown as Carcase 1s on the accompanying CD. The tool, ready for robot mounting and with the modified 'nose', is shown below,

Fig.10 Modified tool ready for robot mounting

Following the trials at MAR, further trials were conducted at Hawkesbury Valley Meat Processors at Wilberforce on carcases that ranged in size from 15 to 30 kgs. The initial trials here were conducted with only the support bar in the middle of the back of the carcase as shown in videos 2 trough 13 on the accompanying CD. As can be seen from the videos this lead to instability in the carcase and caused inconsistent results when eviscerating. Further stabilisation bars and clamps were added as is shown in Fig. 11 below

Fig. 11 Carcase support setup at HVMP.

The trials shown in videos 14 to 24 were conducted with various combinations of theses guide bars with varying success. Issues were encountered when the nose of the tool did not penetrate through the hole cut in the diaphragm, the tool did not get its back edges inside the carcase during the process or the tool failed to clear the neck area correctly.

At this point, due to the inconsistent results being achieved, a re-evaluation of the tooling was undertaken. Videos of the automatic evisceration tool used at Katanning were reviewed and consideration again given to the 'shovel style' tool that was concepted in the initial project application. It was felt that the more enclosed design of a 'shovel style' tool would have greater chance of capturing and removing the viscera. The tool discussed would have a wide curved back section of around 280mm across to allow the tool to break through the diaphragm of the larger carcases but not being too large to cause damage to the smaller carcases. The tool would then narrow to a front edge of about 50mm with a concave nose to allow the tool to traverse down the back bone of the carcase and exit through the neck area without causing damage.

It is envisaged that similarly to the Katanning tool the speed at which the process will be conducted will be higher than has been used in trials to date.

The initial trials conducted with this tool show the path tool path commencing with the concave nose of the tool against the back bone and the blade of the tool almost perpendicular to the spine, videos 23 trough 28 show trials with this tool path. Issues were encountered again with the nose of the tool not getting in though the hole in the diaphragm and the back edges not getting inside the carcase. The tool was successful in removing most of the organs in this orientation but had issues clearing the neck area. Modifications were then made to remove the back edges of the tool and modify the robot program to have the tool enter the carcase in a more vertical plane and have the path be a continuous forward and downwards move as depicted in the sequence in Figure 12 below.

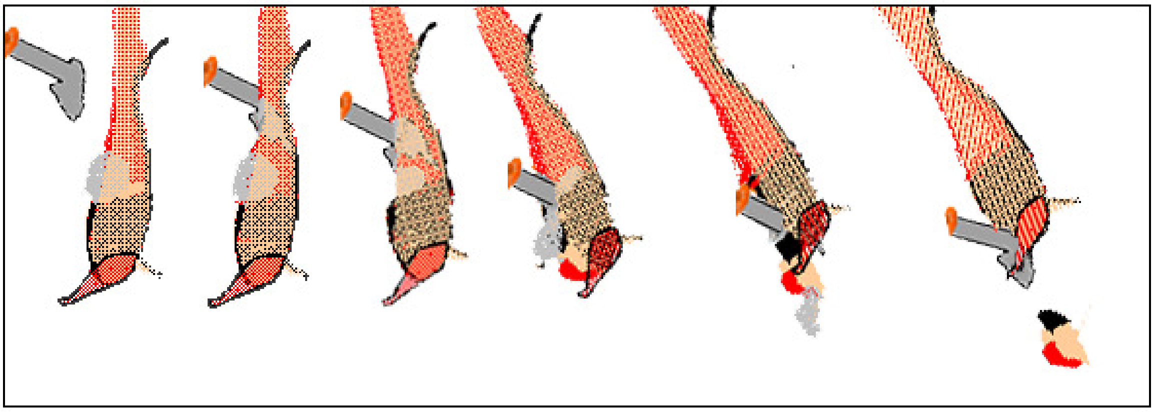

Fig.12 Proposed new robot path for new tool

The results from this proved very successful.

The only 'misses' we had in the final 21 videos had assignable causes these being:

- Carcase 31u – this was unsuccessful because the carcase support stand was not repositioned after it had shifted during the evisceration of the previous carcase.
- Carcase 39s – this eviscerated successfully but tore a rib in the process, this was due to the brisket not being fully cut prior to attempting the evisceration.
- Carcase 40u – here we trialled eviscerating without the preliminary removal of the white offal and cutting of the diaphragm. This proved unsuccessful.

4.6 Cycle time

Cycle time, as measured from the final thirteen videos, for the robot moving from its parked/waiting position – eviscerating the carcase – returning to a safe position is approximately 4.5 seconds. This could be optimised in reality with approach and return speeds being increased and a carcase moving along a conveyor line creating an easier return path for the robot, allowing sufficient time for tool sterilisation within a 6 second cycle time.

5 Success in Achieving Objectives

From the videos taken during the trials and the descriptions above it can be seen that through an iterative process of tool modifications a proven evisceration tool for integration into a robot cell has been designed and tested on carcases in a weight range of approximately 15kg to 30kg. In addition, from the videos it can be seen that the robot can conduct the evisceration process from and then back to its waiting position in under 5 seconds with potential for optimisation of this to allow for sterilisation of the tool in with 6 seconds. .

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

Benefits to be achieved by utilisation and continued development of an Automatic Tool for Robotic Evisceration include:

- Improvements in OH&S;
    - Elimination of risk of operator strain injury from the size, weight and repetitive tasking
    - Elimination of dangerous operational practices
- Consistency;
    - Robotic mounting and control of the evisceration process improves accuracy and repeatability over manual removal systems
- Improved yield through;
    - Improved yield payback by eliminating contamination potentially caused during manual processing
- Labour cost:
    - The system will replace 2-3 units of labour per shift depending on line speed..
- Line Speed:
    - The system can operate at line speed >10 carcases/min.
- Species:
    - The Automatic Evisceration System is suitable for use in lamb, sheep and mutton
- Hygiene
    - An automated sterilisation system will reduce the biological load

Reliability and accuracy, along with processing speed which are critical to the success and acceptance of this technology have been proven in this project.
Production levels at plants such as Peel Valley and Swift would justifies the investment in a robotic system and the recent inclination for Australian processing plants to participate in robotic developments shows the trend the industry is following towards further automation. This is fuelled by acute shortages in labour supply, which will likely get worse in the future.

7 Conclusions and Recommendations

It is evident from the iterative process that has been followed that a simple and low cost Evisceration Tool suitable for attachment to a robot has been developed and proven. With this tool the Evisceration process can be completed (including sterilisation) in under 6 seconds making it suitable for application in plants with lines speeds of > 10 carcases/min.
It is MAR's recommendation that further projects be established to allow the commercialisation of the Automatic Evisceration System to occur. The following lists milestones and possible projects (with the availability of further funding) that MAR see as the necessary next steps for this to be realised:

1. Sensory developments and integration with EV process developed automatically adapting to carcase variability
2. Addition of handling and sanitation modules and extending the capability for performing the tasks of evisceration on the move at the desired cycle time.
3. Performing the task on 50 carcases of varying sizes without stoppage as a milestone, using a robot system and all the modules developed off-line before proceeding to the next stage of R&D implementation.
4. Proceeding to reach in-line integration as the follow up to FULL proof of concept at systems level, including
   - System design to include:
     - Layout including location of all stations (robotic or manual), handling system for transfer form the last step in the line to the new robotic line, safety system and connection to services
     - 3D visualisation
     - Installation phasing and timing
   - System build using production quality tools and modules integrated for off-line testing including:
     - Implementation of the line in an off-site location for functional testing
     - Build and testing
     - Production of engineering documentation
     - Training of engineers on the system off-line
   - Installation on site and operation including
     - Preparation of host site
     - Re-installation of the system on line
     - Initial running at slow speed
     - Ramp up to line speed
     - Training of operators
     - Observation and tuning
   - Line demonstration and consolidation including
     - Consolidation of all design and operations information
     - Preparation of video and training material
     - Demonstrations to invited audience
     - Patenting and licensing considerations
     - Detailed planning and update of commercialisation phase

5. Implementation to the point of commercialisation including:
   - Installation of a second system at a 2nd site as an additional system to the first pilot developed in 4 above.
   - Agreements on sales and marketing plans
   - Documentation of system design for repeat installations
   - Presentation at Exhibitions
   - Other tasks necessary for the sale, installation and operation of repeat systems
   - Full validation of system cost estimated at AU$ 750,000 giving a projected ROI of about 2 years in a 2 shift operation.