finalreport

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Automated Bung Cutter MS15 and Final Report

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Abstract

This project aims to replace the current manual process of Bung Cutting, where a slaughterman uses a hook to pull the bung up slightly to put tension on the tissue around the rectum and then making a circular cut around the rectum, ensures that all pelvic attachments are freed allowing the bung to drop down into the anal cavity. Additionally and if possible MAR will investigate the possibility of including a Bung Evacuation process within the bung cutting tool during initial development and trails for the robotic bung cutting tool.

The project is based upon the integration of the following main elements;

- Carcass handling & stabilisation (Gambrels & Conveyor Rails)
- Sensing technologies
- MAR Developed Bung Cutting Tool
- Robot manipulator
- Tool Sterilisation
- Cell Safety System
- Control System

Executive Summary

This project aims to replace the current manual process of Bung Cutting, where a slaughterman uses a hook to pull the bung up slightly to put tension on the tissue around the rectum and then making a circular cut around the rectum, ensures that all pelvic attachments are freed allowing the bung to drop down into the anal cavity. Additionally and if possible MAR will investigate the possibility of including a Bung Evacuation process within the bung cutting tool during initial development and trails for the robotic bung cutting tool.

Through extensive offline and online trials the project has developed a Bung Cutting tool that, provided it is accurately placed over the bung area, will successfully cut and free the bung. There are a number of challenges that the system still faces however, including:

- Sensing required for accurate tool location
- Inverted bungs caused by the high vacuum
- Cross contamination caused by the stabilisation conveyor
- Quality of tool sterilisation
- Cycle time concerns with increased carcass rates

While it is felt that these challenges can be overcome there is concern that with the increased carcass rate proposed at GMP and the range of carcass sizes and breeds processed at GMP that cut quality and tool cleanliness will be compromised. MAR believe that the system could be successful in a plant that runs at a slower carcass rate and processes a more consistent size and breed of carcass, however it is felt that the best course of action would be to halt any further work on the system at GMP

Contents

1 Background

In 2007/08 MAR completed Stage 1 Bung Cutter Trials "P.PIP.0157" working with project participating plants "Gundagai Meat Processors and Wammco Katanning" with trials showing very promising results.

The purpose of the project was to asses the suitability of a standard pig de-bunging tool to process sheep by testing it in two different Australian plants. These trials proved successful with results indicating positive for future use of the tool as a manual operated or automated bung cutting (ringing) operation.

Based upon results the next progression of the development is the integration of the bung cutter equipment to a robot to produce a fully automated system.

2 Project Objectives

This project aims to replace the current manual process where a slaughterman uses a hook to pull the bung up slightly to put tension on the tissue around the rectum and then making a circular cut around the rectum, ensures that all pelvic attachments are freed allowing the bung to drop down into the anal cavity.

Additionally and if possible MAR will investigate the possibility of including a Bung Evacuation process within the bung cutting tool during initial development and trails for the robotic bung cutting tool.

To substitute human operator(s) with an automated system doing the same task(s).

The project is based upon the integration of the following main elements;

- Carcass handling & stabilisation (Gambrels & Conveyor Rails)
- Sensing technologies
- MAR Developed Bung Cutting Tool
- Robot manipulator
- Tool Sterilisation
- Cell Safety System
- Control System

At the completion of the Project, MAR will have completed the following to MLA's satisfaction:

- Perform staged trials of major system components at MAR with GO/NO GO decisions at each stage prior to finalising design and manufacture of system
- Perform on-site tool trials to include sufficient operational production trials at GMP. (GO/NO GO based upon results)
- Developed a automated bung cutter solution that satisfies the production criteria's specified by GMP
- Develop a solution to suit GMP that is adaptable to other processing plants Australia wide.
- Test and prove the solution at MAR in controlled environment as proof of concept prior to installation on-site
- Implement into GMP's processing facility a fully function Bung Cutter System
- Commission and trial system to achieve specifications according to the contract with client
- Train operation and maintenance staff to competency in maintaining and operating equipment

3 Methodology

The project will be completed following the Milestones below

Milestone 1 - Initial Design & Project R&D

- MAR will conduct and review with MLA and GMP 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.
- Initial Design R&D, includes potential designs for future sites and ensuring the design meets the requirements of potential future processors who will take on this technology.

Milestone 2 – Bung Cutter Tool Initial Development & Trials

- Investigate possible inclusion of bung evacuation within bung cutter tool
- Design of bung cutter tool suitable for robotic adaption and operations
- Purchase components and manufacture of bung cutter tool (Prototype)
- Perform operational tests and trials at MAR
- Transport Prototype tool and setup for trials at GMP
- Perform on-site tool trials at operational trials at GMP
- Videos, reports and documentation detailing results of trials

GO / NO GO

Milestone 3 – Vision & Sensing Trials

- Design vision and sensing equipment setup and components
- Purchase components and manufacture of sensing setup suitable for trials
- Setup and install vision and sensing equipment at MAR
- Perform sensing trials at MAR
- Setup and install vision and sensing equipment at GMP
- Perform sensing trials at GMP
- Perform bung cutting trials at MAR using results from vision on-site trials as parameters
- Videos, reports and documentation detailing results of trials

GO / NO GO

Milestone 4 - Plant Layout and System Design

- Complete component and plant layout design based upon results from trials
- Submit a working system design based upon results from trials for approval by GMP

Milestone 5 – Robot System Components

- Purchasing of robot system components and delivery to MAR to begin system build integrating and programming.
- Robot, Base Frames, protective covers
- Bung Cutter tool components including sterilisation

Milestone 6 – Control System and Sensing Components

- Purchasing of control system and sensing components and delivery to MAR to begin system build integrating and programming.
- Control Systems, PLC, PC and HMI systems
- Sensing system components including lighting and protection

Milestone 7 – System Components

- Purchasing of system components and delivery to MAR to begin system build integrating and programming.
- O/H rail conveyor system and gambrel stabilisation
- Safety System, floor mats and fencing components

Milestone 8 – System Build

- System Build & Installation at MAR
- Component build and assembly R&D working on learning's to reduce complexity, cost and manufacturing techniques.
- Initial offline programming of robot, HMI, PLC & control system interfacing

Milestone 9 – System Setup

- Mechanical & Electrical Setup & Test of System
- Test tooling robotic operated
- Setup & Test safety systems
- Trial programming of robotic movements
- Integrate Sensing System
- Component Integration R&D

Milestone 10 – System Testing & Trials

- Trial and troubleshoot of system
- Robot cutting trials
- Setup and test manual and semi auto operations
- Setup and test full auto cycle operations of system
- Component Integration R&D

Milestone 11 - System FAT at MAR

- Factory Acceptance Testing of system 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
- Trial of cycle time
- Videos, reports and documentation of FAT

Milestone 12 – Site Preparation for installation (GMP)

- Prepare site for installation
- Modification and extension to conveyor systems
- Relocation of existing conveyors equipment
- Preparation of Services (water, power, etc)

Milestone 13 - On-Site Staged Installation of System

- Equipment Transport to Site
- Installation of robot, safety and conveyor systems
- Installation of sensing, sterilisation
- Electrical and services installation

Milestone 14 – 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 15 – System Commissioning and Production Trials

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

Milestone 16 - Site No.1 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 Milestone 1 - Initial Design & Project R&D

The project was commenced in mid 2010 and a Project Risk Assessment was submitted at that time along with the draft system layout shown below.

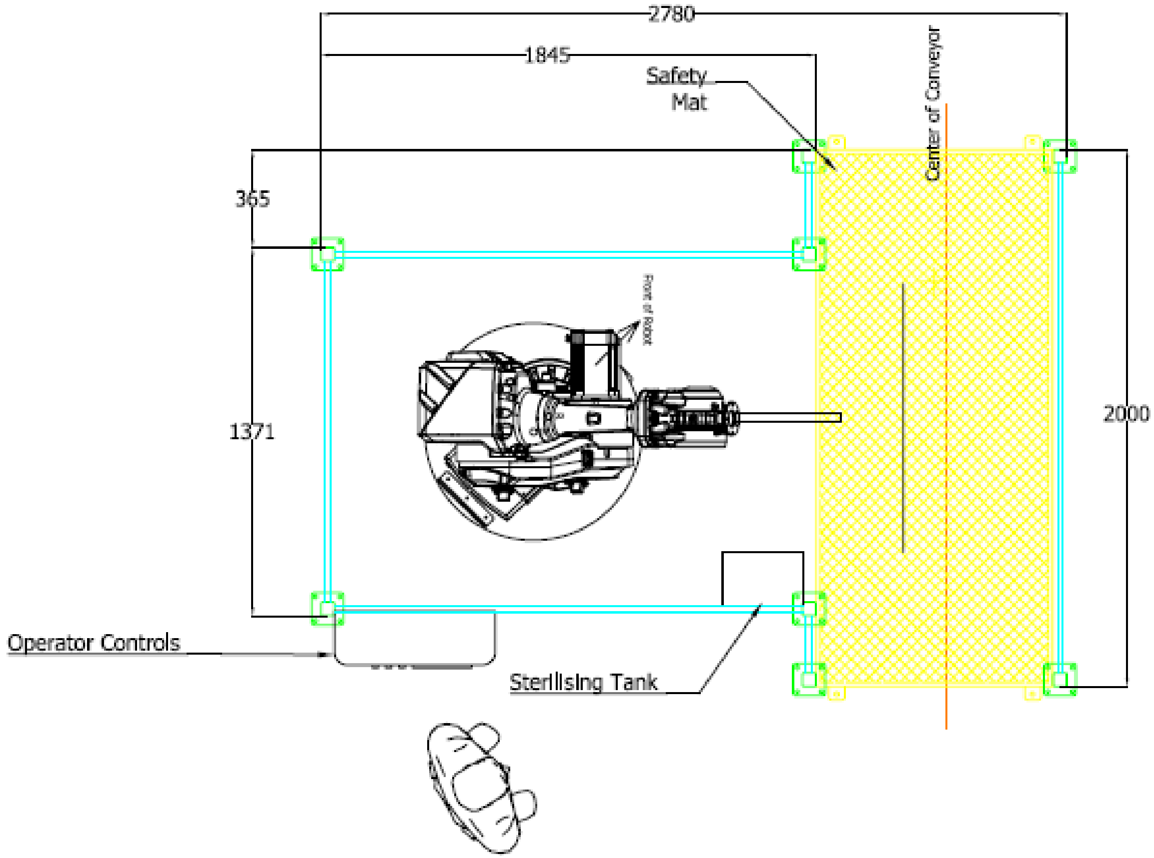

Fig. 1 Draft System Layout

Initial design R&D involved a site visit to Peel Valley Exporters where the manual Debunging tool, shown below, was used to obtain an idea of the effort and path required for successful debugging. Reports and videos of past trials on bung evacuation have also been reviewed and contact was made with Peter Mc Donald, Maintenance Manager at GMP, to organize a site visit to view the existing tool in operation as part of MS 2 for this project.

Fig. 2 Manual Debunging tool

Contact was also made with Freund in Germany with regard to their experience in regards to robot mounted bung cutting and evacuation tools. Below in Fig. 3 is an image of a potential design that they have looked at in the past, however this has gone no further than the drawing board stage. This design would require a two stage operation with a rotation of the robot roll face in between. It is felt that this design would not satisfy the requirements for this project from a cycle time point of view and further research/design needs to occur with a view to developing a more integrated tool. This will form the basis for the development and trials for MS 2 of this project.

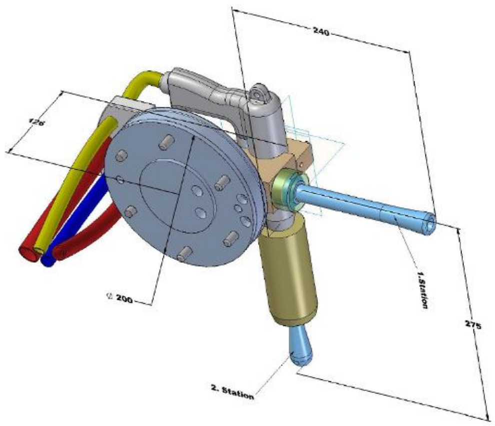

Fig 3 Freund design for automated evacuation and debunging tool

4.2 Milestone 2 - Bung Cutter Tool Initial Development & Trials

With a view to designing a combined robotic Bung Cutting and Bung Evacuation tool for Lamb, MAR researched these processes that are currently carried out successfully in the pork industry in Europe. Contact was made with Freund Slaughter Tools in Germany and discussions held with regard to their experiences of combining the two processes in one tool. These discussions revealed that no such combined tool existed for a manual or automated process. The best they could offer was a concept of a combined tool, this image is shown below. Use of this concept was deemed not appropriate from a cycle time point of view since it would involve a two step approach, first insert the tool to evacuate then remove the tool, rotate the roll face of the robot and then re insert to debung, this process taking longer then the 6 second cycle required to allow the process to be suitable for the majority of Australian abattoirs.

Fig.4 Freund concept tool

With this in mind and a view to developing a combined robotic Bung Cutting and Bung Evacuation tool MAR first procured a Jarvis manual bung cutting tool and manufactured an adaptor plate so that this tool could be mounted to a robot roll face for trial purposes. The plan was then to develop a manual evacuation tool and trial this before designing the combined tool.

The images below show the Jarvis tool mounted to a robot. The robot was programmed and the tool manually actuated to successfully perform the debunging operation.

Fig.5 Jarvis Manual Bung Cutter mounted to robot

A manual evacuation tool was then designed and manufactured. The tool consisted of a 25mm stainless steel tube with 2 small stainless pipes welded to the outside of the tube. These pipes were connected to manual 'pistol grip' valves that supplied air and water to the front of the tool. The thinking behind supplying the air and water to the front of the tool was that these would aid in preventing vacuum lock where the colon was sucked up the evacuation tube. This had been experienced in previous trials conducted by Gundagai Meat Processors and prevented the colon from being properly evacuated. The tubes and their welded location are shown in the image below.

Fig.6 Manual Evacuation tool with air and water tubes welded to outside of the tube.

The issues that were experienced with this design were:

1) That the end of the tool was too sharp and tore through the colon
2) The air and water were directed out the front of the tool which tended, when the colon was not torn to fill the colon with water.

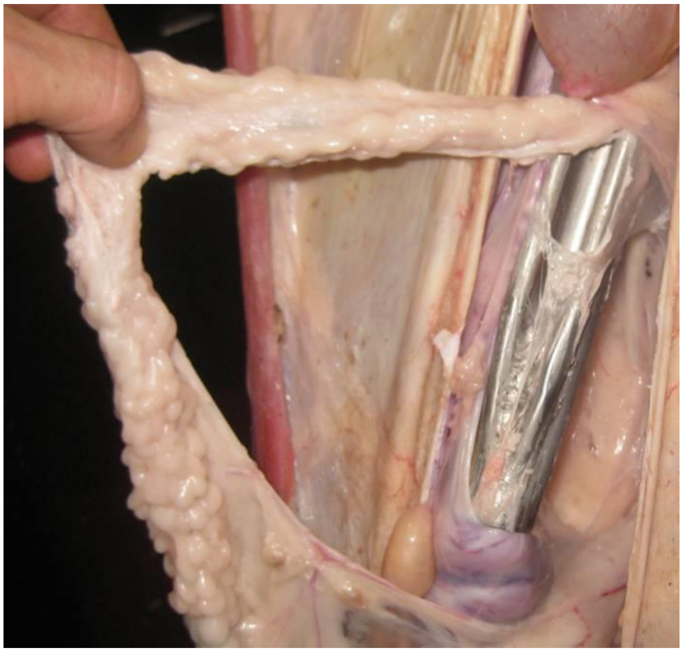

Fig. 7 Colon punctured by tool

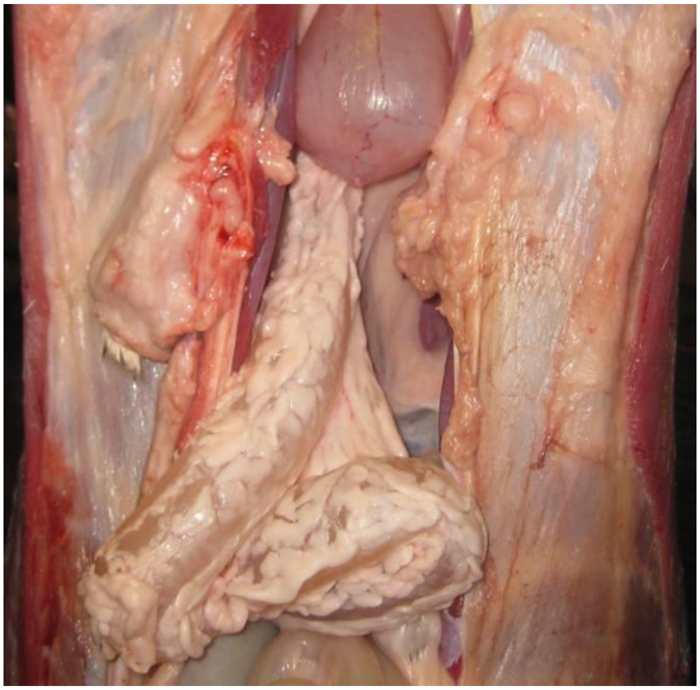

Fig.8 Colon filled with water

The tool was redesigned to include a second tube (32mm in diameter) around the outside of the existing 25 mm tube. This tube was rounded at the end and the air and water pipes welded to the back of the outer tube so that the air and water were forced between the to tubes and exited such that they were directed back up the evacuation tube instead of out the front of the tube. The images below show this.

Fig.9 Modified 'nose' of manual evacuation tool

Fig.10 Top view of modified Manual Evacuation tool showing 'Pistol Grip' valves welded into outer tube.

Fig.11 Manual Evacuation Tool

The pistol grip valves allowed the flow of air and water to be regulated so that there was minimal spray out the front of the tool and vacuum lock of the colon was eliminated and successful evacuation of the colon was achieved with this tool. The images below show the before and after shots of a colon full of pellets then the colon empty of pellets (to a depth of approximately 150mm) after being evacuated.

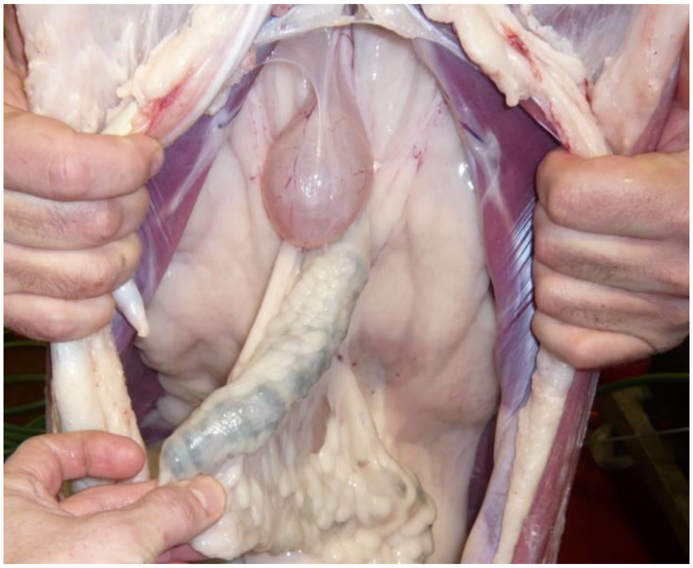

Fig.12 Colon Full of Pellets

Fig.13 Colon after evacuation

Following the success of these two trials design was commenced on a combined tool.

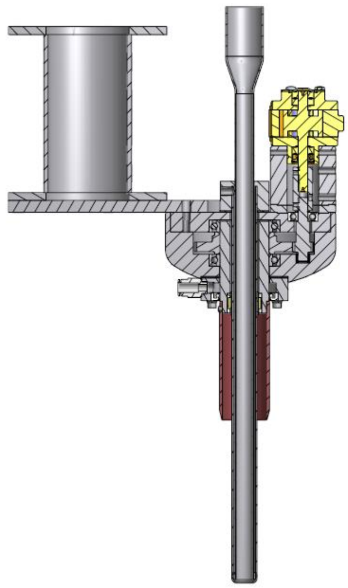

Fig.14 Concept drawing of Combined Tool

At this point it was agreed that the robot should be purchased to allow proper trials to be conducted. The images below show the tooling mounted on the robot. Initial trials were conducted at Hawkesbury Valley Meat Processors on limited carcasses and due to the manual nature of this plant the decision was made to transport the robot, tooling and temporary vacuum system to GMP so that more carcasses could be tested and operation of the tool verified.

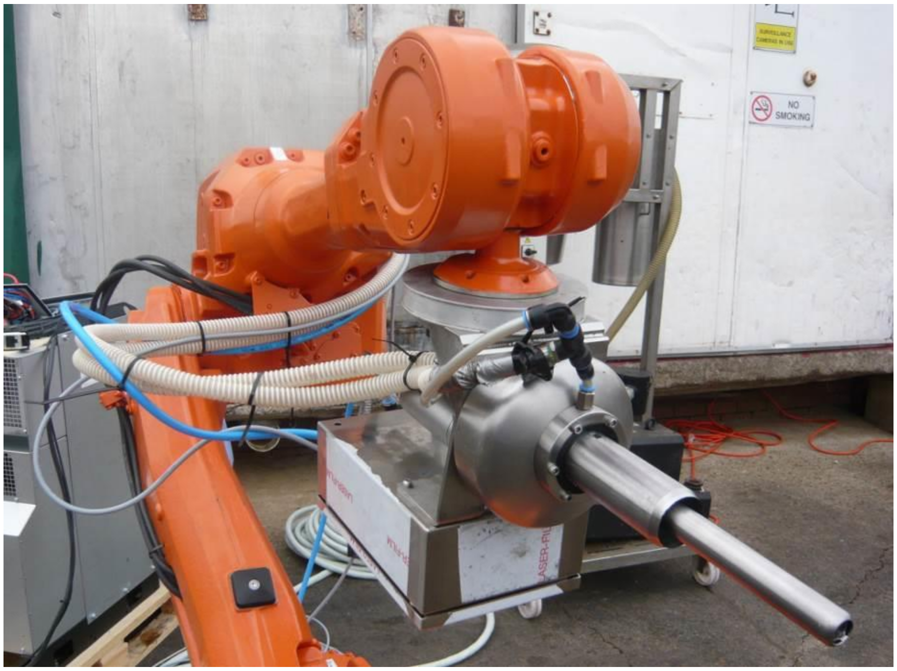

Fig. 15 Sheep Auto Bung Cutting System Tooling and Robot ready for shipping to GMP

4.3 Milestone 3 - Vision & Sensing Trials

While the above tool development was taking place, confirmation was sort that the proposed vision system was able to successfully find the bung hole to allow cutting and evacuation to occur. A site trial was conducted with a TYZX Stereo Vision Camera, the setup is shown below.

Fig.16 Camera setup GMP during vision trials

Trials, showed that if a clear shot of the anus was obtained then the hole could be successfully found using appropriate vision tools, however if the hole is obscured by the tail as shown in Fig. 2 then there are real issues in correctly locating the hole.

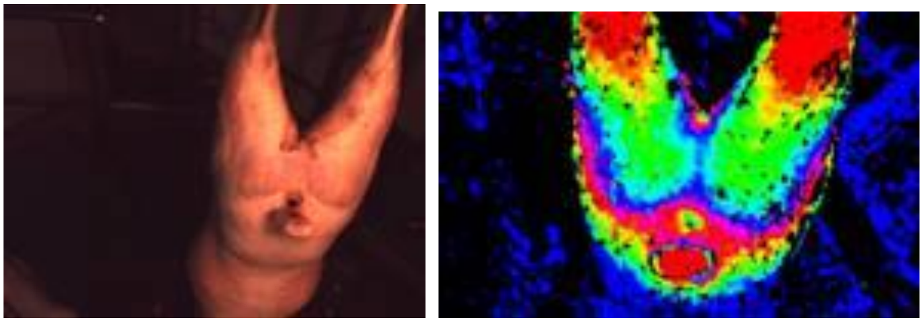

Fig.17 Clear view of Bung Hole

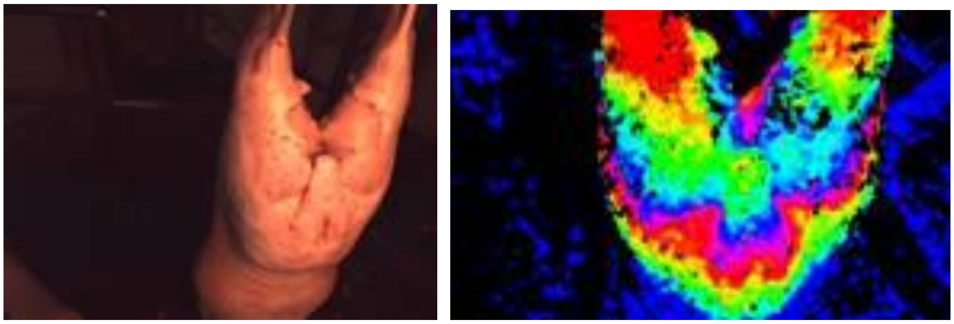

Fig.18 Bung Hole obscured by tail

Obviously for correct location of the bung hole the tail will need to be moved from this position. A number of trials were conducted and a number of options were evaluated including a suction gripper and a pin gripper to pull the tail out of the way. While some success was achieved neither was considered ideal for a production reliable system. Images of the grippers are shown below.

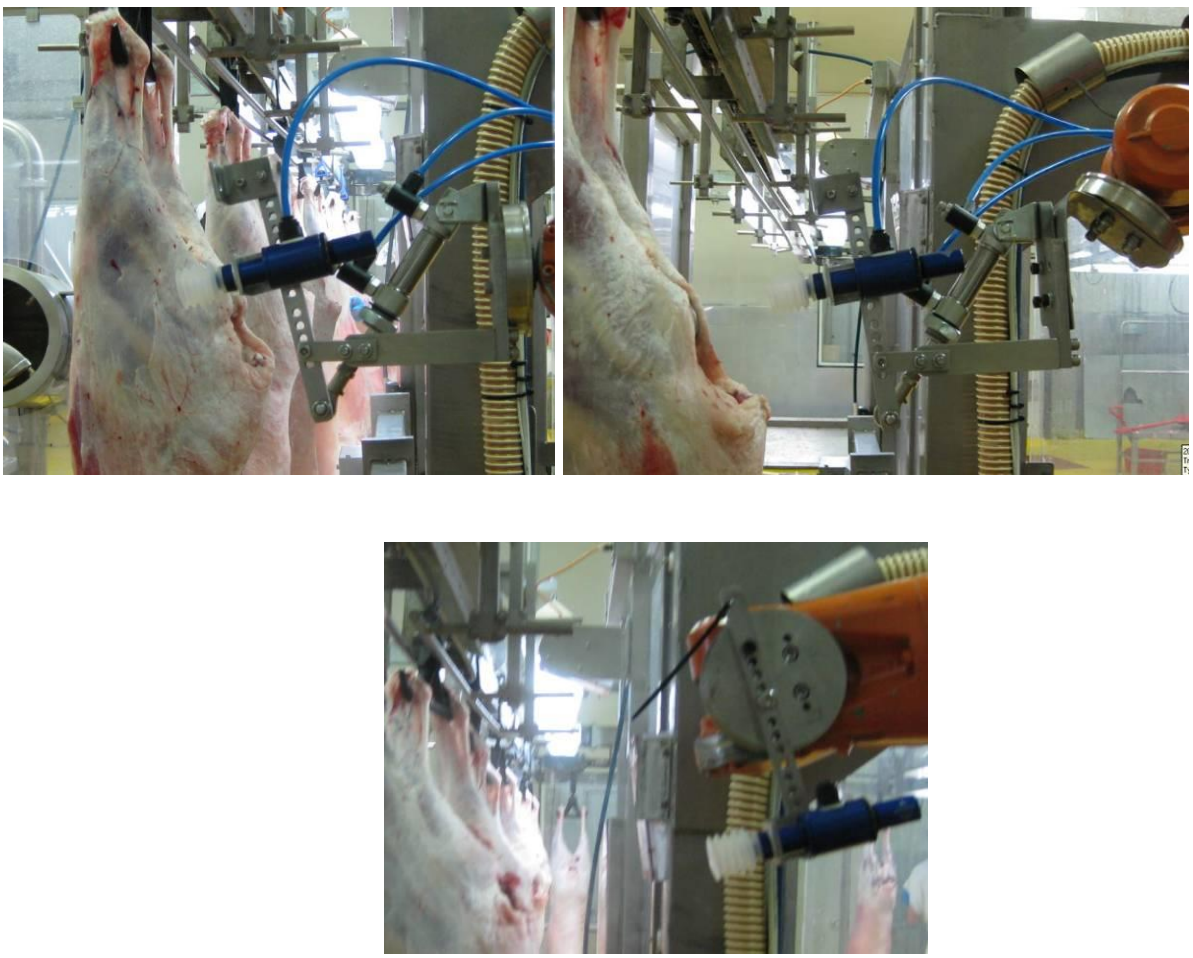

Fig.19 Suction Cup gripper mounted to Rear Vac San Robot at Peel Valley for trials

Fig.20 Pin Gripper

4.4 Further Tool Trials and development

Following transport of the system to GMP trials were conducted and revealed a number of issues with regards to:

- Cutting tool diameter and length
- Poor evacuation of pellets
- Poor vacuum
- Tail covering bung
- Orientation (hung by 4 legs) causing:
    - Excessive faecal pellet contamination
    - Excessive soft faecal contamination
    - Exposed intestines and other offal

Following a site meeting incorporating representatives from GMP, MLA and MAR during which further trials were conducted the following was decided:

- Evacuation would be performed as a separate task.
- Required tool dimensions need to be determined by measuring a large number of bungs following which tools of appropriate diameter will be fabricated and trials conducted to determine the most suitable size.

From these measurements and trials it was decided that:

- A tool of 47mm diameter was the most suitable
- The carcass needs to be hung from 2 legs to avoid issues with contamination and exposed organs and offal as shown below:

Fig. 21 Exposed organs

The carcasses need stabilisation during the bung cutting operation and hence the stabilisation bar shown in the below images was added:

Fig. 22 Gambrel/carcass stabilisation

- MAR should pursue further design work to develop a method of moving the tail out of the way of the bung hole.

As a result, the following concept was developed and prototype fabricated:

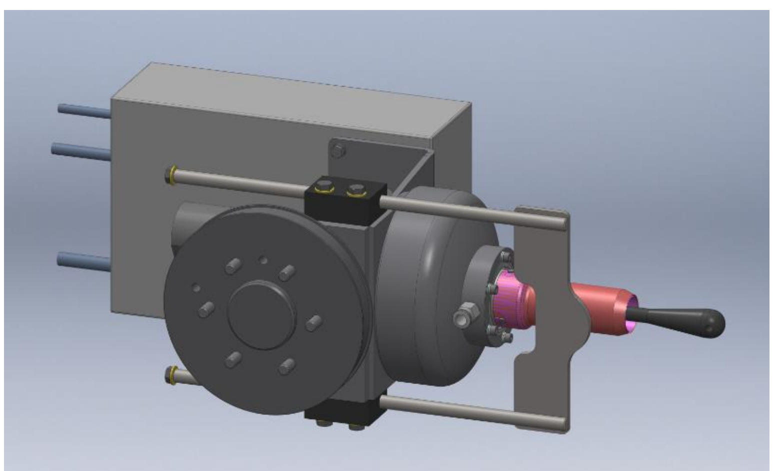

Fig. 23 Tool design with tail mover fitted.

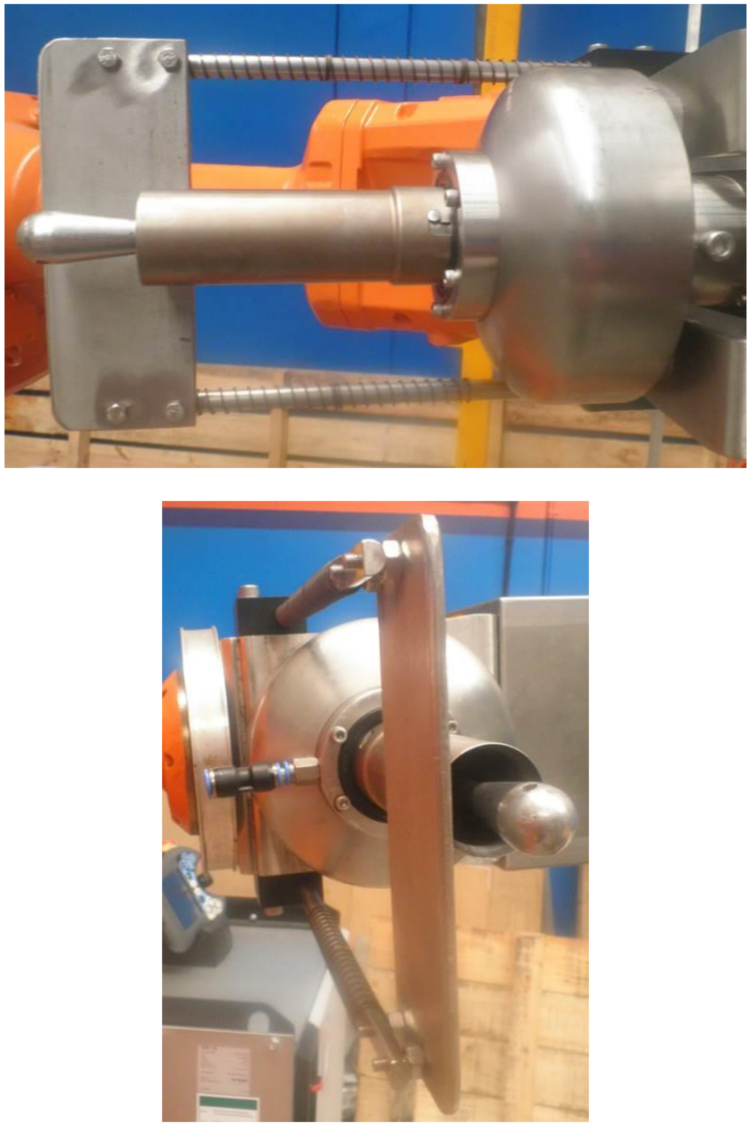

Fig. 24 Tool with tail mover fitted

Manual trials with this tooling were conducted but proved to be difficult with the heavy and cumbersome tool. This lead to the additional Stationary Bung Cutting trials Project P.PSH.0621 funded jointly by MLA and MAR.

4.5 Stationary Robot Trials

The setup of the stationary robot trials is shown in the images below:

Fig.25 Stationary robotic trial setup at Gundagai Meat Processors

In total 21 carcasses were trailed these being a mixture of males and females of varying weights. In all cases the bung, bladder and vagina on females were freed. Three small issues were encountered during the trial process:

- On one carcass (video 41) the tail mover failed to move the tail out of the way. This was due to the carcass having very flat buttock muscles and the tail lying against the bung hole. It was agreed with all present that this could have been overcome with the use of sensing and that it was not necessary to modify the robot program to suit this particular carcass.

- On one male carcass the urethra was nicked causing the bladder to leak. The comment from ‘Colley’ was that, because of its location in this carcass, manual cutting would have resulted in the same.

- Particularly on females a small amount of the colon was left just near the tail. Peter Edwards commented that this was not an issue to him as the tail was removed in a later process anyway. However modifications were made (video 53 and 54) to the tail mover in an attempt to relieve the pulling or stretching effect of the tail mover on the skin in that area. These modifications had a minimal effect and in trials on the final two carcasses (video 56 and 57) the tail mover was retracted manually just before the vacuum was applied. This allowed the skin around the tail to get sucked into the cutter and the bung was freed without leaving any colon behind.

The conclusion agreed to by all parties involved in the trials was that they were very successful and that the project should move to the next stage of development. This stage will involve online trials with the tool mounted on the robot and will incorporate the following:

- Design & Build of new components, these being
    - an upgrade of the Tail Manipulator such that retraction of the manipulator prior to cutting is automated
    - online carcass stabilisation to eliminate swing and movement of the gambrel/carcass during the cutting process
- Setup and temporary installation of robot system online on the kill floor at Gundagai Meat Processors
- Commission and test temporary robotic bung cutting cell
- Online Robotic Bung Cutting trials

4.6 Online Robot Trials

The online trials aimed to achieve the following goals and enable continuation of “P.PSH.0535” ;

- Ensure Bungcutter tool operates with consistent quality over a range of carcasses (breed, size and gender)
- Ensure new tail manipulation operates consistently providing sufficient access to bung for cutting and ensuring no “bung skin” remains near tail bone.
- Ensure sensing technology implemented provides sufficient data for operations over multiple carcasses.
- Ensure cycle time can be achieved for operations at Gundagai Meat by performing trials with full cycle functionality
- Ensure any major project risks are alleviated prior to continuation of project and system build for installation.

The images below show the Online Trial setup on the kill floor at Gundagai Meat Processors. The stabilization bars, the gambrel sensing and height sensing, robot, robot base, tooling and vacuum system used for the trials are all shown.

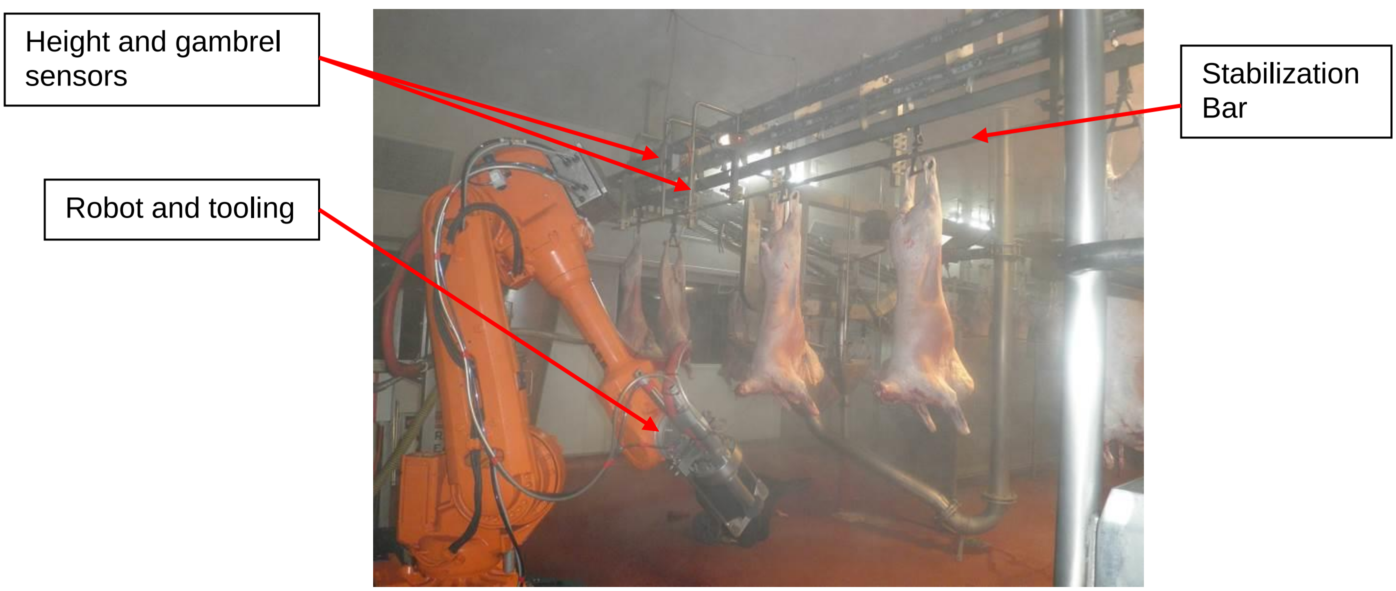

Fig.26 Online Robot Trial setup at GMP June 2012

The tooling with new pneumatic tail mover is shown in the image below

Fig.27 Tool with pneumatic talk mover fitted.

Following the setup above, trials were conducted in the presence of Daryl Heidke from MLA. The sensing and trigger routines were tested, the robot was cycled and the Bung Location Routine was tested with no carcasses using the Offline Trial program as a starting point. Initial online trials were then conducted. It was found that the programmed cycle was too quick, the cutting tool did not cut for long enough and the tail manipulator sequence was not correct. A number for modifications were made to the sequence including:

- Slowing the cycle down.
- Modifying the tail manipulator sequence.
- Increasing the cutting time.
- Increasing the time for vacuum to be achieved.
- Modifying the amount the tool retracted once vacuum was achieved.

All of these changes had some effect but the results achieved were not consistent and with the carcass online and moving at production speed it was difficult to adequately observe exactly where the process was going wrong. To enable us to obtain a better understanding of the issues it was decided to revert back to an offline setup.
To commence the trials off line the pneumatic cylinder, used to control the tail manipulator, was removed and replaced with springs to return conditions to the state they were in during the initial offline trials. The original offline program was loaded into the robot, trials were conducted and the following changes were made to the cutting sequence to further improve the results:

- Angle of approach
- Speed of cutting
- Speed of retraction before cutting
- Length of time for vacuum to be achieved

The improvements resulted in a cycle time of between 6-7sec's with the results of the cuts being predominately good to very good. For the cuts that were not good it was felt that the addition of sensing to properly detect the height of the carcass would result in an improved outcome. The pneumatic cylinder was reintroduced into the sequence and the fact that there was height detection sensors mounted on the line it was decided that we were at a point where we could reintroduce the system to online trials. The trials achieved good success on all the males processed, however, had issues with the females. The robot has been programed in such a way that on females in the offline trials both the bung and the reproductive organs are captured under vacuum and cut away. What was found during the online trials even with the cycle running at the speed it was off line, the results were inconsistent. The issues encountered were:

- Missing the opening to the vagina and hence all the female reproductive organs.
- Missing the opening to the vagina but cutting away the organs.
- Cutting rump meat or bones in an attempt to capture the female organs.
- Missing the bladder.
- Locating in the vagina rather than the bung.

At this point trials were switched back to offline to enable further refinement of the robot paths/program in an attempt to overcome the issues listed above. In addition it was felt that a larger area for vacuuming up the bung and female organs would be of benefit. Trials were conducted between October 2012 and February 2013 during this time the following occurred:

- A lot of time was spent refining robot sequence, cutting speeds, wait times for vacuum, angles of approach.

- A shroud that was able to slide along the outside of the cutting tool was added and it is shown in the image below. This increased the area capable of vacuuming up the bung and female organs.

Fig.28 Shroud on the outside of the tool

- Additions were made to the stabilization of the carcass. A bar was added across the hip area of the carcass to limit the swing of the carcass when the de bunging process is taking place.

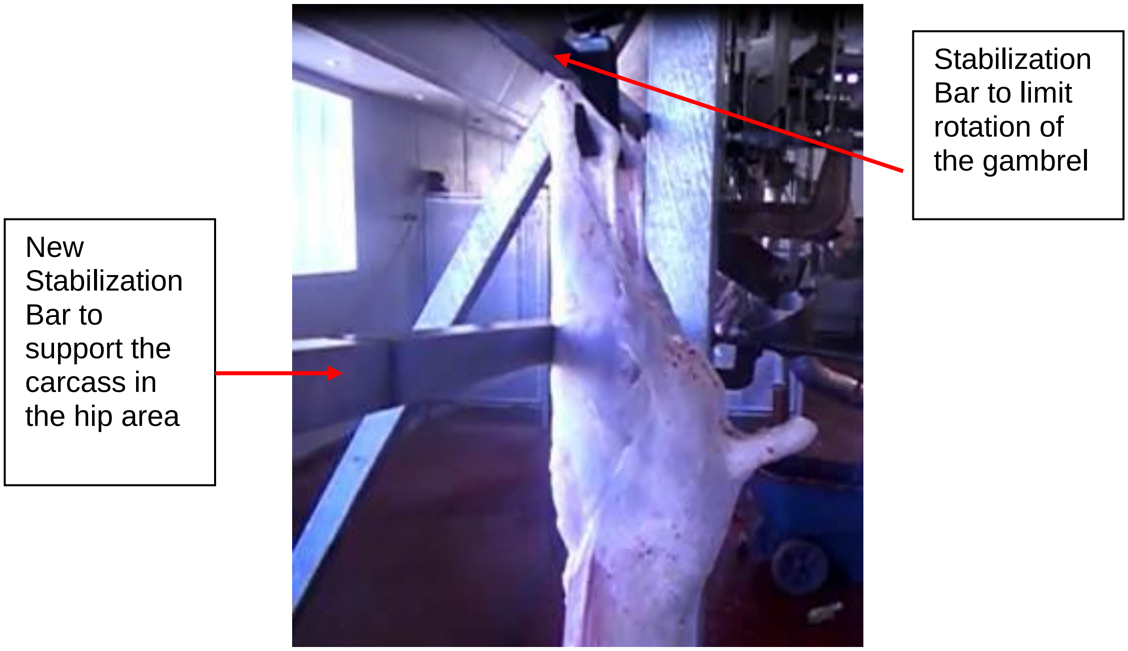

Fig.7 Stabilization bars

- Modifications were made to the tail manipulator to improve its robustness and ensure it ran smoothly and did not jam up.

Fig.29 Upgraded Tail manipulator, tool shown with cutter removed.

- Finally due to continued issues of not getting enough vacuum at the end of the tool to 'suck' up all required material, and locating in the vagina rather than the bung, trials were conducted with the centring pin removed. This improved the vacuum dramatically and resulted in all females trialled being cut correctly.

With all these modifications in place further refinements were made to the sequence and a cycle time of 5.5 sec was achieved.

At this point it was decided that the system was ready to be trialled online again. The stabilisation bars simulated during the offline trials were designed, fabricated and installed and shown in the image below. A third bar that cannot be seen in the image below is rubbing against the back of the hook as it runs along the rail to inhibit it 'skipping' ahead of the chain dog while the debunging process is taking place.

Fig.30 Online stabilization bars

The Online trials were conducted on the 27th of March 2013 in the presence of Darryl Heidke from MLA. A total of 15 carcases were trialled. All cuts were successful except for one where the H Bone was cut. This has been put down a possible sensor error and carcass swing.
The only other issues that were experienced were when the bung was full of pellets where the bung was cut and released but damaged in the process. This would be alleviated if the bung was evacuated. Hence, from the results achieved it can be said that:

- The Bung Cutting tool is capable of consistently processing the range of carcasses, both males and females, that are processed at GMP
- The tail manipulator operates effectively providing sufficient access to the bung for all carcasses processed.
- The sensing used provides sufficient data to enable the system to process multiple carcasses successfully

- Cycle time was not fully tested during online trails for safety reasons. Trails, however, did not indicate any problems in achieving the cycle time required for GMP. Offline cycle time trails where completed with simulated sterilisation implemented. Cycle times of approximately 7.6 seconds where recorded with room for improvement making a production rate of 8/min achievable and well within the requirements of GMP who currently run around 6/min.
- These trials have alleviated the major risks identified in the project and at the completion of the 15 carcasses Darryl indicated that he was satisfied that the system had achieved the required outcomes for the Online Trial Project.

Following these trials the conclusion is that the current tool design and concept is capable of consistently processing the range of carcasses encountered at GMP.
MAR and GMP agree that the full Bungcutter development project P.PSH.0535 should be re commenced now that major project risks have been alleviated.

The developed Bungcutter tool however does require further refinements to improve on the design and to optimise it for eventual production. At this point the project was varied again to allow the incorporation of the following tool upgrades:

- Shroud design
    - Automation of the shroud around the cutting tool needs to be designed and implemented
    - Longer shroud 10-20mm may assist obtaining quicker vacuum
    - Shroud needs more rigidity and friction to make it harder to push back - need shroud to push back under Vacuum only
- General Tool Improvements:
    - Tool needs to be setup for automated production
    - Tool needs to have through tool sterilisation implemented with necessary controls.
    - Improve linear rail setup on Tail Swiper, improve pneumatic control speed, flow and pressure adjustments
    - Need longer cutting tool and Tail Swiper on final version to promote easier access for Tail Swiper ensuring it is well clear and does not influence cut cycle
    - Need Longer cutting tool and Tail Swiper on final version to prevent gearbox hitting carcass at full depth
- Cutting Tool
    - Cutting tool length needs to be optimised
    - Various size Tools required to fine tune and improve range of cut
    - A range of larger diameters tool and shrouds required (~+5mm increments)
    - Change cutter location Pin directions

With regards to the production process, Evacuation of the colon prior to bung cutting needs to be implemented as part of GMPs' process.
This must be implemented to avoid unnecessary spillage and contamination during the automated process.

4.7 Further Tool Improvements

4.7.1 Through Tool Sterilization

One of the recommendations to come out of the Online Bung Cutting trials, conducted throughout 2013, was that through tool sterilization needed to be integrated into the new design of the Bung Cutting tool. It was found during the trials that external cleaning of the tool was not enough to adequately remove pellets and carcass material that became trapped inside the tool during the bung cutting process. The following images show the existing design followed by the new improved design.

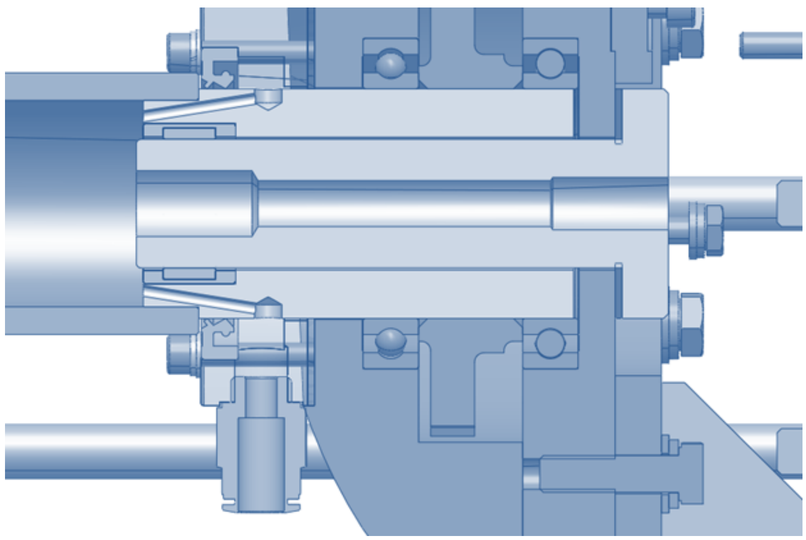

Fig.31 Existing Drive Hub assembly

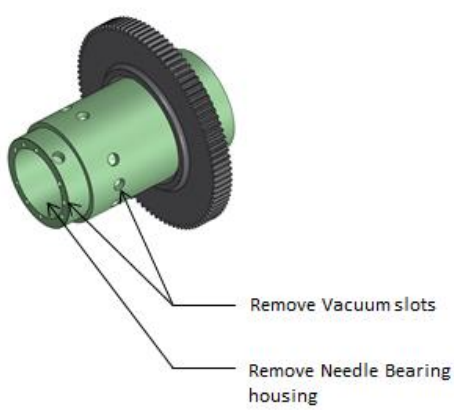

Fig.32 Existing gearing

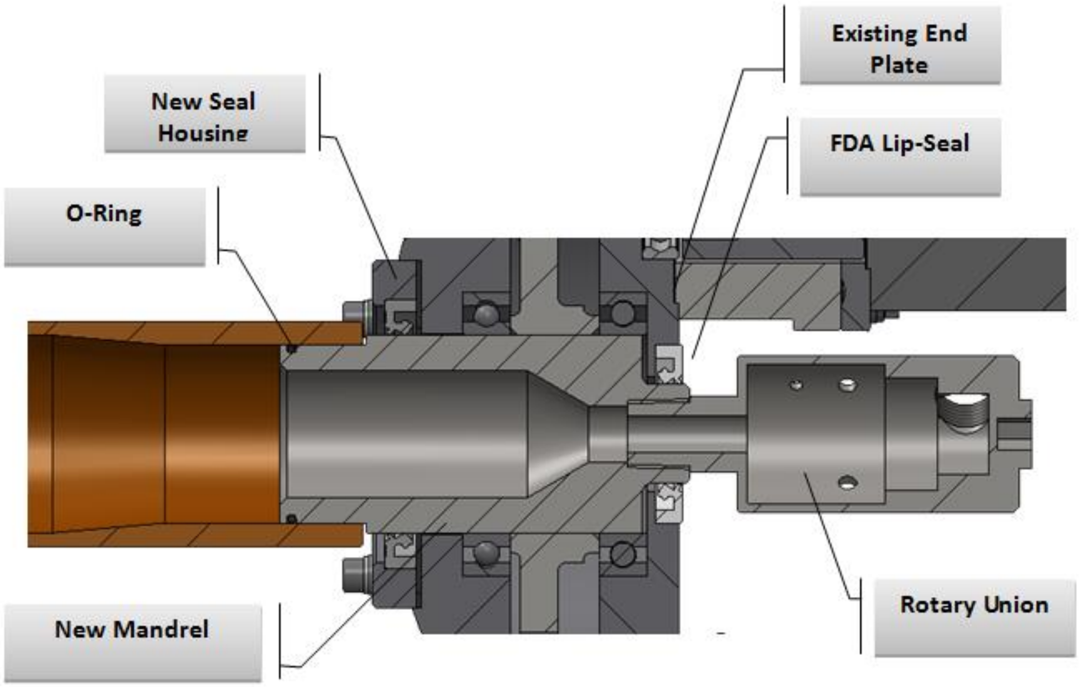

Fig. 33 New Hub Assembly

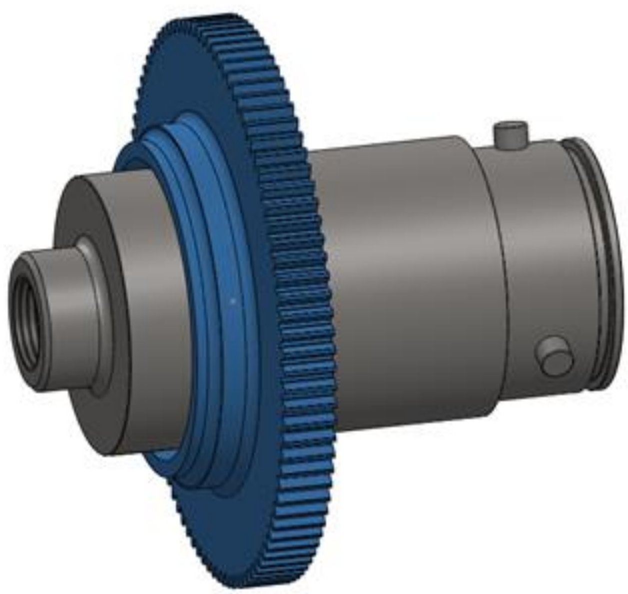

Fig.34 New gearing design

The modifications that have been made are:

- New mandrel and new gearing eliminating needle bearing

- Incorporation of a rotary union, to serve a dual purpose:

  1) to allow vacuum to be piped to the centre of the tool for use during the cutting process
  2) to allow 82 degree water to be piped to the centre of the tool for sterilisation purposes

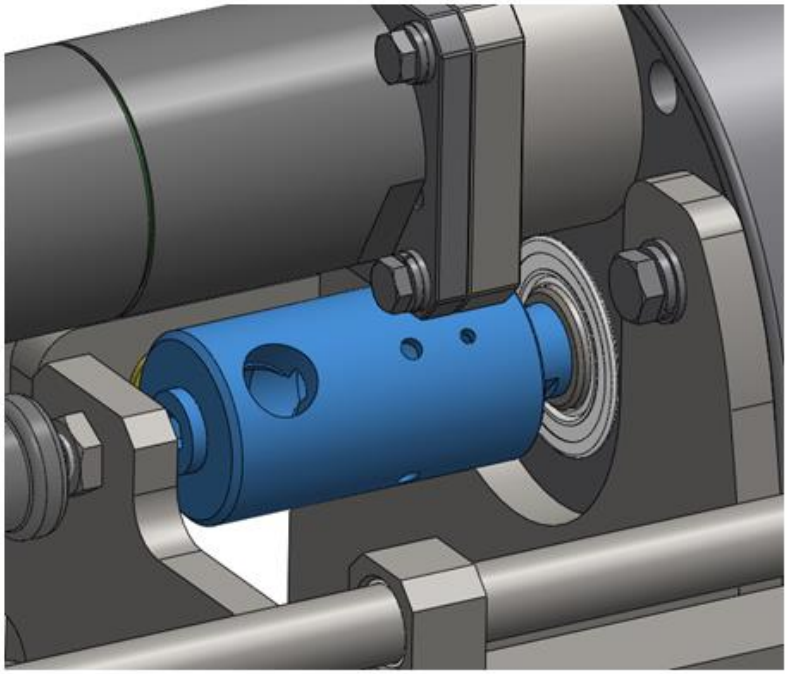

Fig.35 Close up of Rotary union allowing through tool sterilisation

DUFF NORTON 5000 Series

Operating Parameters

MEDIA
Water, Steam, Hot Oil, Air

PRESSURE*
750 PSI (Water), 120 PSI (Steam)
100 PSI (Hot Oil), 300 PSI (Air)

TEMPERATURE*
300° F (Water), 350° F (Steam), 395° F (Hot Oil)

SPEED*
1,000 RPM (NPT), 3,600 RPM (MT)

THREADS
- 1/4" to 2" NPT
- BSP, BSPP & Metric Threads Available

MATERIAL
300 Grade Stainless Steel

Fig.36 Specification of rotary union designed

- addition of lip seal to protect the rear ball bearing
- Removal of front vacuum port, all vacuum now through rotary union
- O Ring added to reduce vacuum loss
- Larger overlap between Rotary Knife and Drive Mandrel (bayonet fitting) to minimise angular misalignment.

With these changes it can be seen that this area has been made less complex and more robust as well as providing the through tool sterilization required.

4.7.2 Refinement of Tail Swiper and Pneumatics improvement

The requirements for improvement in this area were as follows:

- Improve linear rail setup on Tail Swiper, improve pneumatic control speed, flow and pressure adjustments
- Need longer cutting tool and Tail Swiper to promote easier access for Tail Swiper ensuring it is well clear and does not influence cut cycle
- Need Longer cutting tool and Tail Swiper on final version to prevent gearbox hitting carcass at full depth

The image below shows the initial redesign concepts for the pneumatics and linear sliding aspects of the tail swiper and the vacuum shroud.

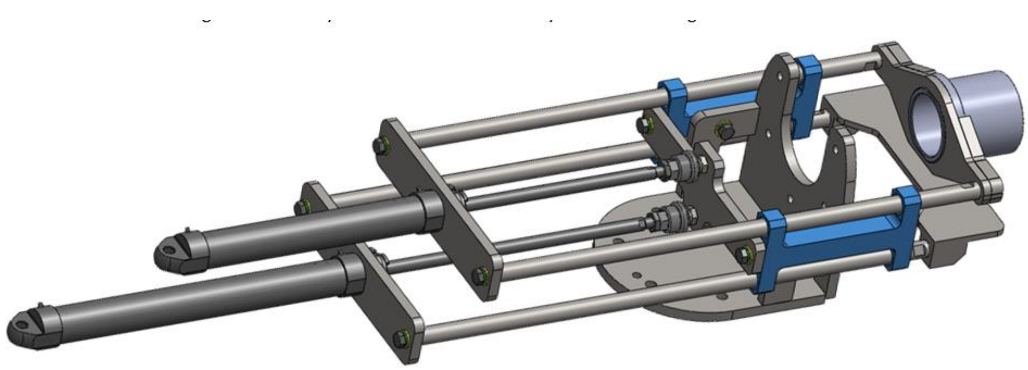

Fig.37 New pneumatics design

Improvements include:

- FDA Polymer Sleeve Bearing/Press Fit

- 16.0mm Dia Sliding Rod
- Additional pneumatic Cylinder to automate vacuum shroud movement
- Stainless Pneumatic Cylinder
- Longer stroke driving the Tail Swipe Blade for more retraction away from vacuum shroud
- Use of floating joints at the cylinder rod end to minimise misalignment issues.

The details of the bearings and floating joints are below:

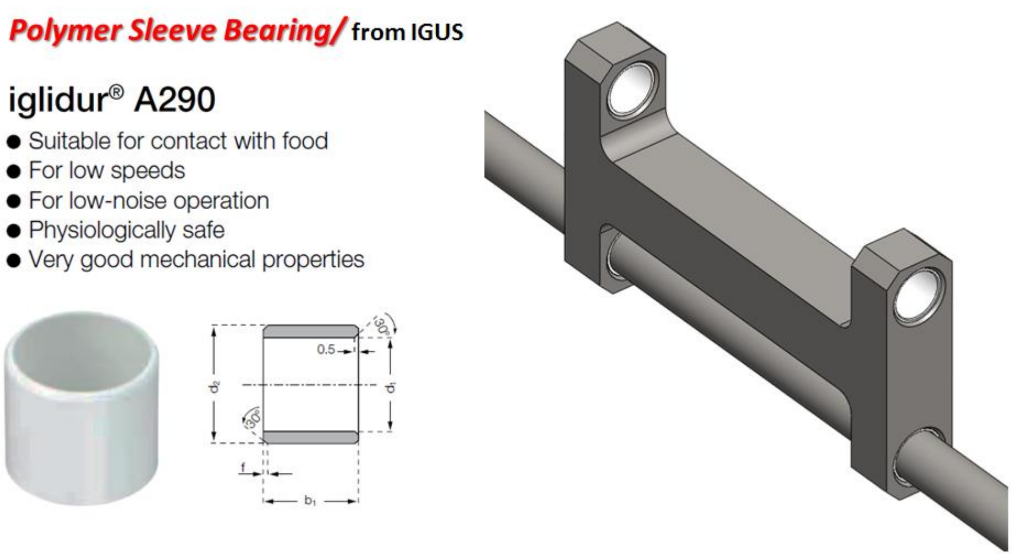

Fig.38 Sleeve bearings used in new design

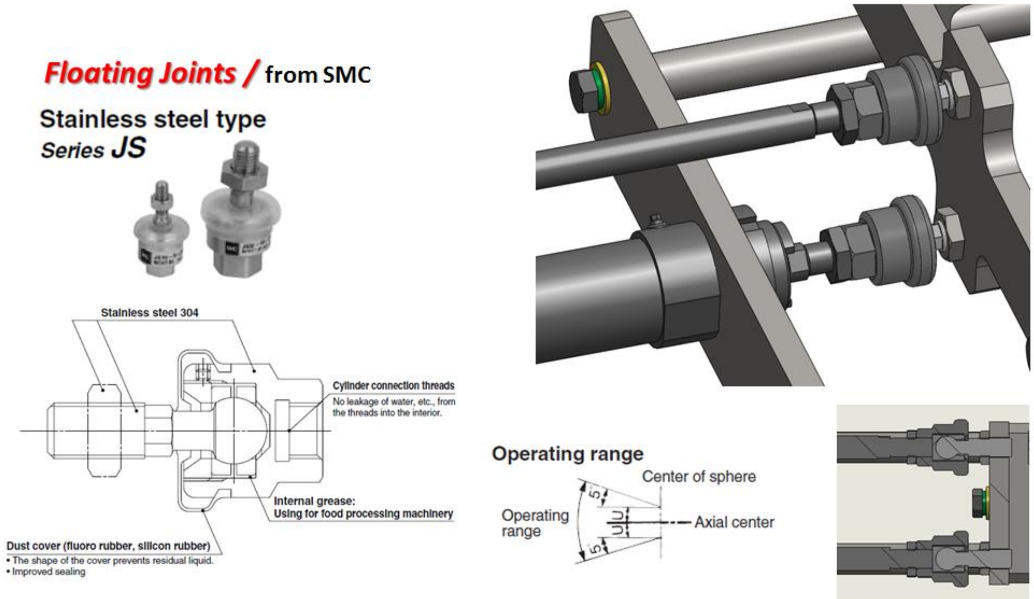

Fig.39 Floating joints used in new design

Further internal review of this however felt that the design made the tool too long with potential ongoing maintenance issues. Refinement for the design was made to decrease the length of the tool and reduce potential maintenance issues. Specifically, the cylinder barrels have been fixed into position. On the current tool, the barrels move while the rod is fixed. The feeling is that having the design as shown in the following picture will reduce the risk of equipment failure.

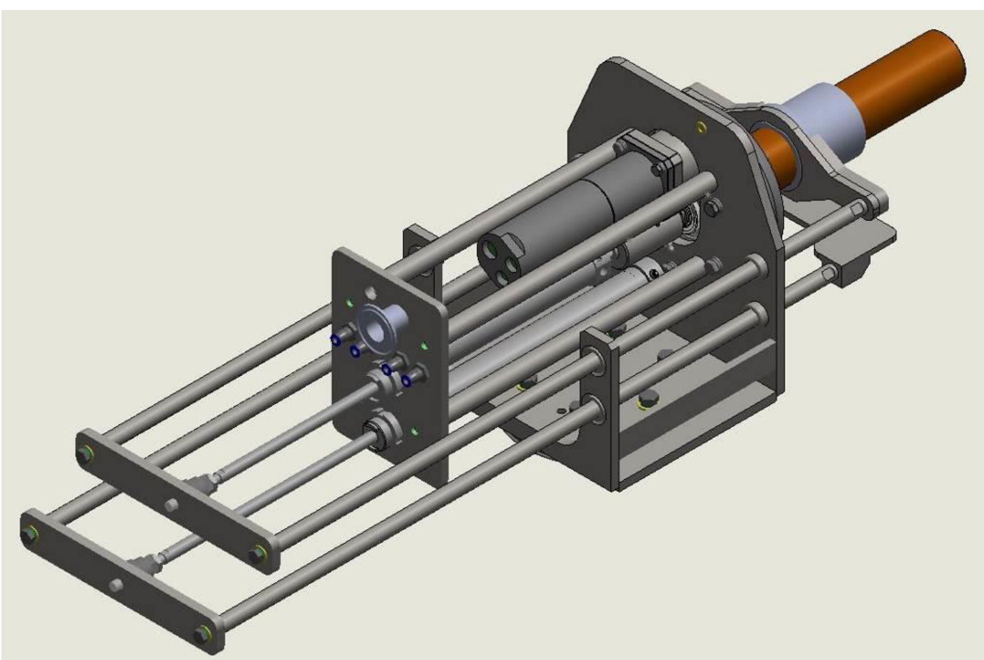

Fig.40 Image of improved cylinder-mounting design

4.7.3 Automation of tool shroud design

From the Online Bung Cutting Trials that were conducted it was recommended that the following be incorporated into the new design for the Shroud:

- It's operation needs to be automated, the Shroud used in the Online trials had to be manually repositioned after each carcass was processed. The image below shows the Online Trial setup:

Fig.41 Tooling used in Online trials

- Shroud needs to be longer to assist in obtaining quicker vacuum
- Shroud needs more rigidity and friction to make it harder to push back, it needs to push back under Vacuum only.

As can be seen in the descriptions above and the image below, the tool shroud has been automated in the new design. It is pneumatically controlled and is independent of the spinning blade. The pneumatics and new bearing setup have improved the rigidity and provide controlled movement of the shroud.

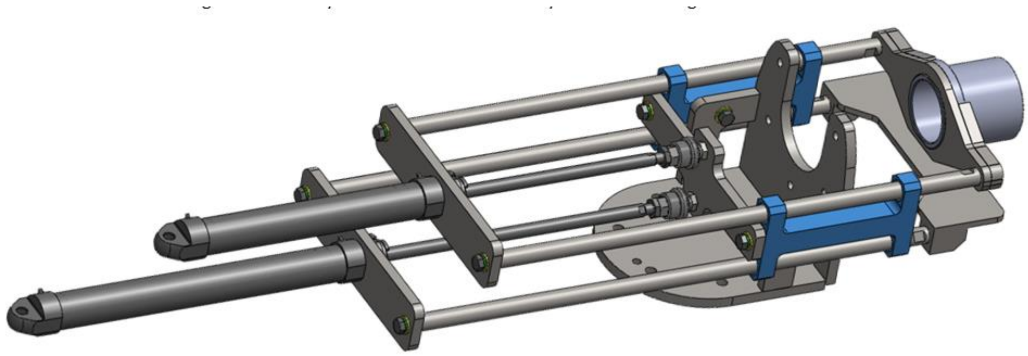

Fig.42 Automated tool shroud

The images below show the shroud assembly, it has been designed to enable it to changed out to suit different cutting blade sizes.

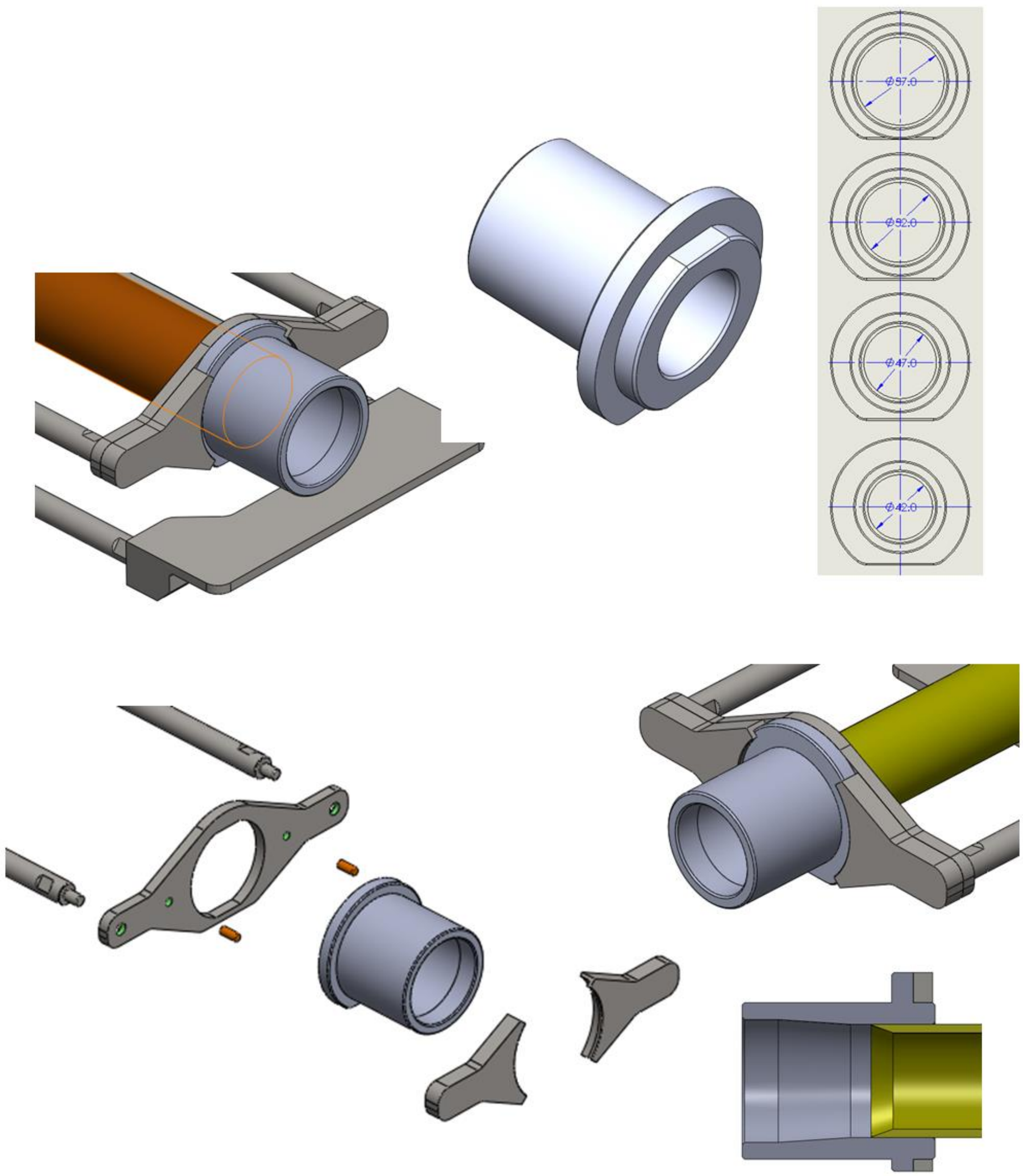

Fig. 43 Shroud assembly, setup so that shroud sizes can be changed.

4.7.4 Modifications for variations to cutting tool length

Recommendations from the Online Cutting Trials with regard to the Cutting Tool were:

- Cutting tool length needs to be increased to eliminate the gear box of the tool touching the carcass
- Various diameter tools are required to fine tune and improve range of cut. Trial tool is 47mm in diameter, fabricate tools 42mm, 52mm and 57mm in diameter for trial.
- Change direction of bayonet fitting, the current fitting allows the tool to come loose as the cutting blade turns.

The images show the 4 sizes of tool designed all are 100mm longer than the tool used in the Online Trials.:

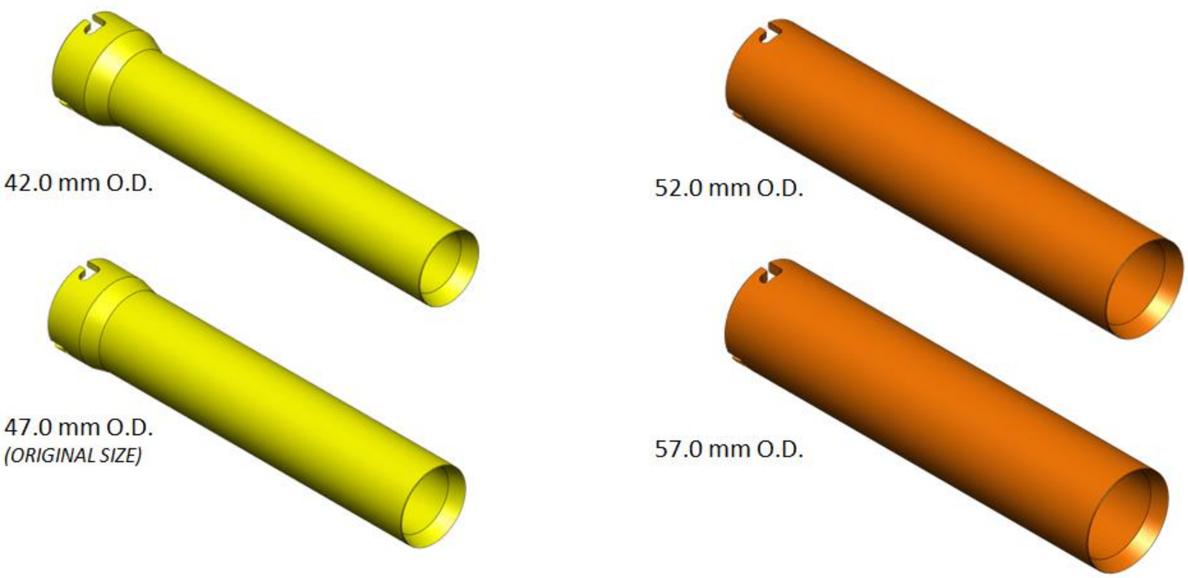

Fig. 44 Different tool sizes designed for testing to determine optimum size

The specification of the steel to be used is:

440C MARTENSITIC STAINLESS STEEL BAR (AS 2837-1986 440C)

- High carbon straight chromium high hardenability martensitic stainless steel.
- Used for parts requiring a combination of excellent wear resistance, plus reasonable corrosion resistance.
- Typical applications are:
  Ball Bearings and Races,
  Bushings
  Cutlery
  Chisels
  Knife Blades
  Pump Parts
  Surgical Instruments

Other Design improvements:

In addition to the points above improvements have been made to the tool mounting bracket to improve clean ability and provide less areas for entrapment the image below shows the new design.

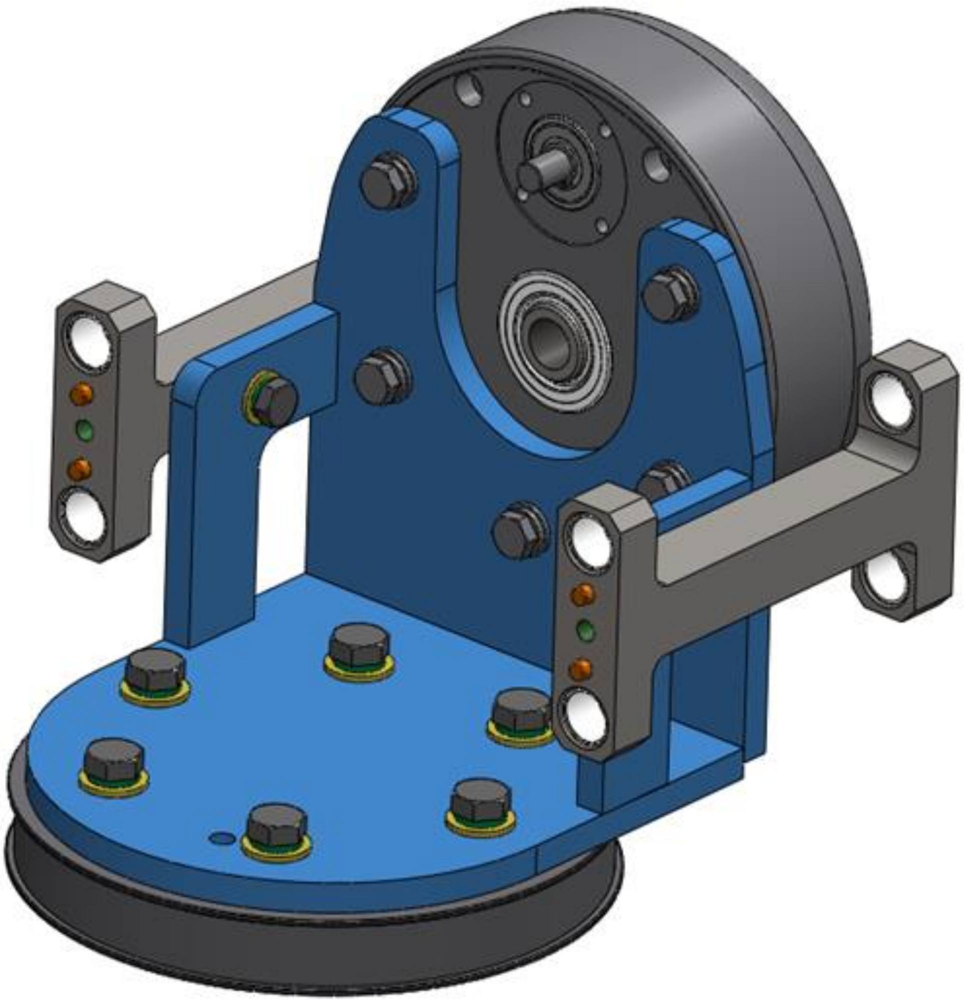

Fig. 45 Improved design of tool mounting bracket

Overall New tool design

The images below show the overall new tool design. The new design addresses the following points that were marked as needed redesign following the Online Bung Cutting Trials at GMP during 2013:

- Introduction of through tool sterilization
- Refinement and improvement of tail swiper and pneumatic setup
- Automation of the tool shroud operation
- Modification to the tool length and design of various tool diameters for selection of optimum tool diameter for use at GMP.

In addition a new cleaner design has been achieved. These new designs will now be fabricated in preparation for installation at GMP.

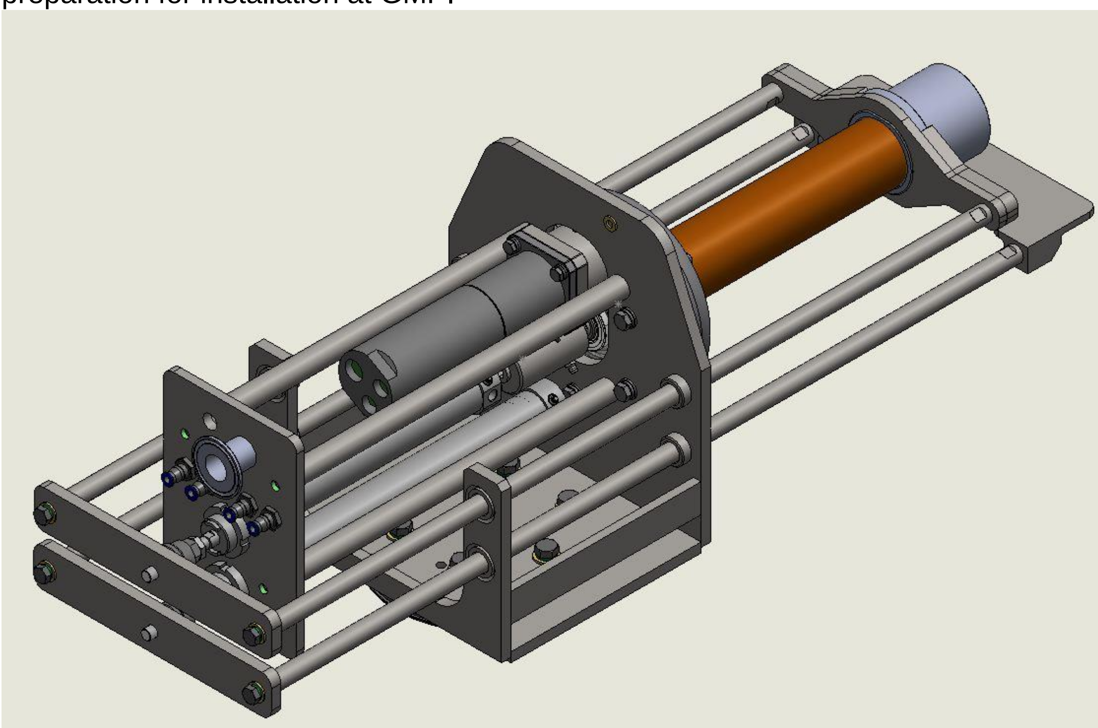

Fig. 46: Tool with Swiper & Shroud extended; cover for services not included

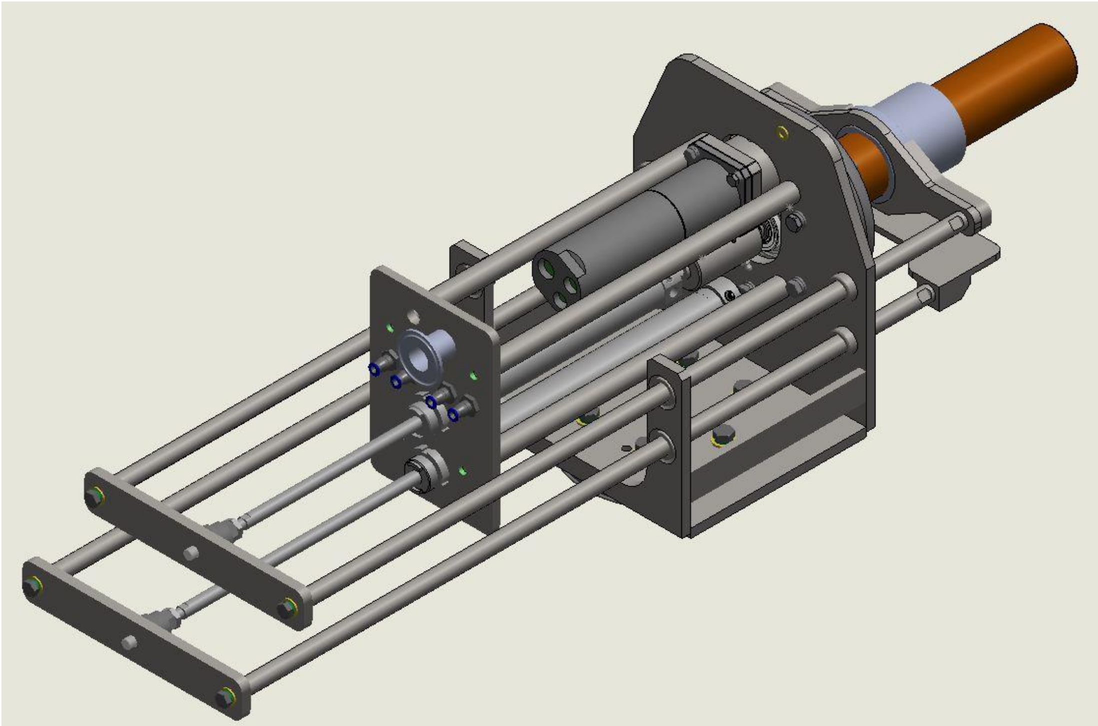

Fig. 47: Tool with Swiper & Shroud retracted; cover for services not included

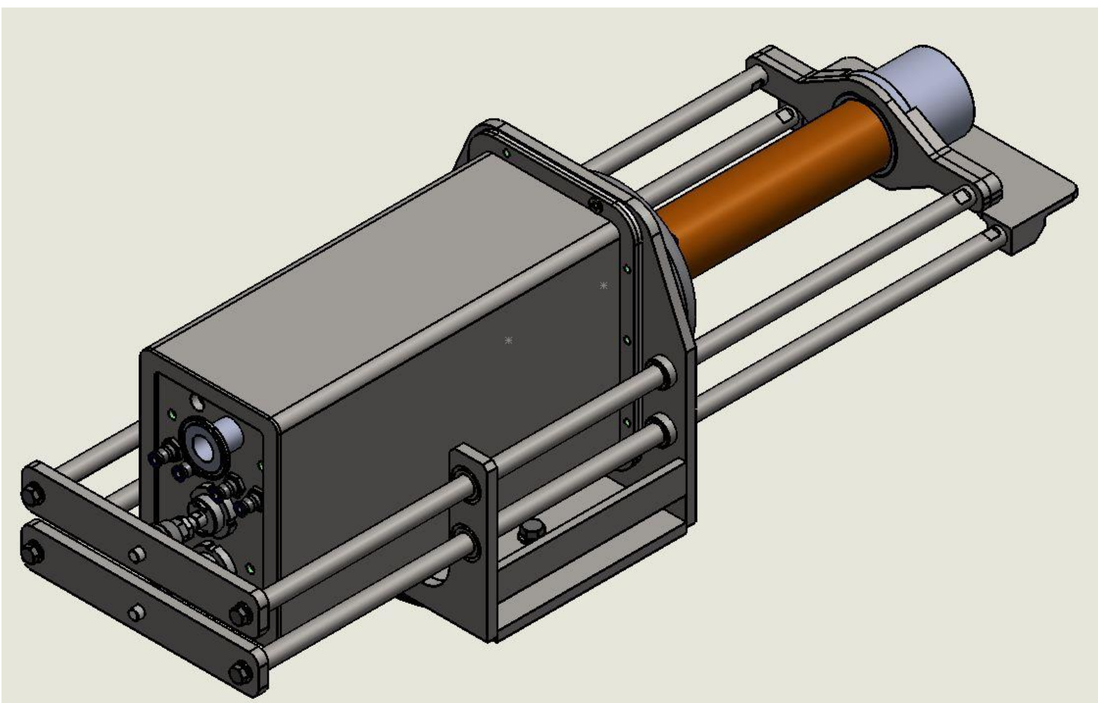

Fig. 48: Tool with Swiper & Shroud extended; cover for services included

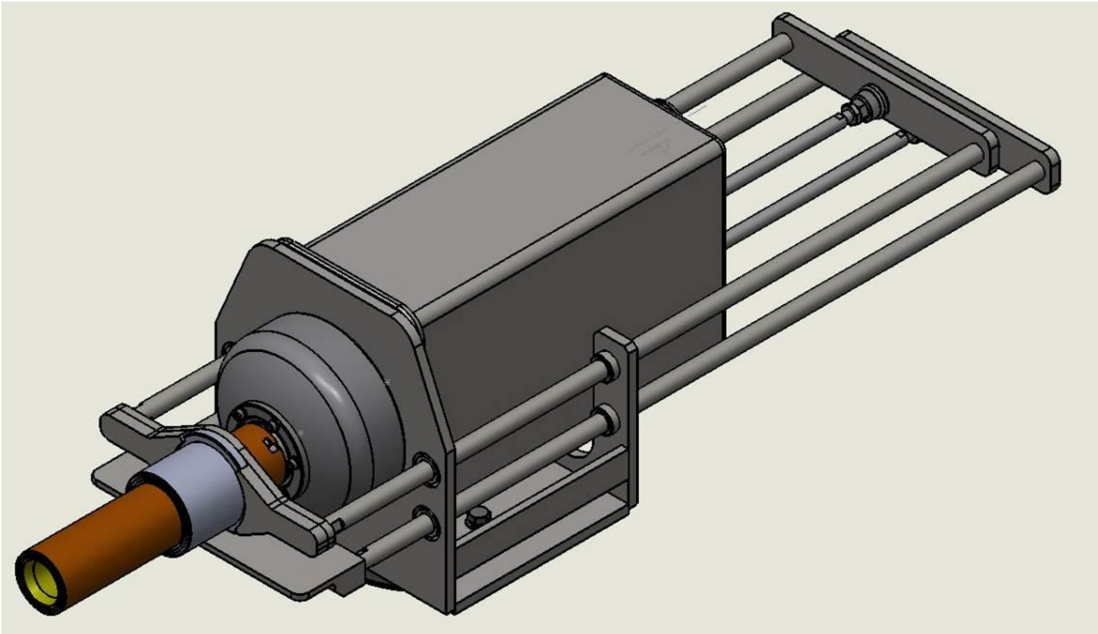

Fig. 49: Tool with Swiper & Shroud retracted; cover for services included

4.8 Cell installation and new Tool Trials

MAR conducted trials with the new tool on site at Gundagai Meat processors during February 2014. The trials proved that the tool can operate successfully and produce very good results when the tool is placed accurately in the bung area. However there were issues experienced with the quality of the cut when the tool was not accurately located. The main reason for poor location is illustrated by the two images below. Currently from a sensing point of view, as can be seen by the red laser dot in Fig.50, we are sensing the carcass from above only. With this measurement the starting point for the robot is determined. It can be seen that while this measurement gives good data for the starting 'height' of the robot it gives no information on what the starting 'depth' (position between the robot and carcass in a direction horizontal to the floor) is. The image's below show why this is an issue. Fig.50 shows a carcass with a rounded rump and prominent bung area while Fig.51 shows a carcass with a flat rump and recessed bung. From these figures it can be appreciated that the bung in Fig.50 will be closer to the robot than the bung in Fig.51. Hence, as was found in the trials conducted, when the robot goes to cut carcasses like that shown in Fig. 51 it has a tendency to cut into the tail bone and not cut the bung correctly.

Fig. 50 Carcass that resulted in a good cut, red laser dot for height detection can be seen

Fig. 51 Carcass that resulted in a poor cut due to a flatter rump.

MAR felt that it was possible to resolve this issue with the installation of a further sensor to detect the ‘depth’ of the carcass. In addition the installation of an automated stabilisation conveyor to eliminate the drag that was experienced with the stationary stainless steel bar and an improved vacuum system were needed to improve results. With this in mind the installation of the bung cutter cell proceeded, the image below shows the completed cell on the floor at GMP.

Fig. 52 Cell installed at GMP

4.8.1 Outstanding issues

Inaccurate tool location

As can be seen in the image below the additional sensor was added during the installation of the cell. However the results achieved on trials conducted following the completion of the installation of the cell still did not result in consistent location of the tool over the bung.

Fig. 53 The two Optical Sensors used, one detecting crotch height one detecting the thickness of the carcass in the bung region.

Fig.54 Image showing where the sensors measure on the carcass

These Optical Distance Sensors are the same as those used in other robotic installations within the meat industry (Brisket cutter, Sani Vac and Kidney Fat Removal).
Using the crotch sensor as an example of the issues we are encountering with the readings received back from these sensors, the graph in figure 55 below is the reuslts we would expect to see if the sensor was reading correctly, ie shorter readings on the legs with the longest reading in the centre of the crotch.

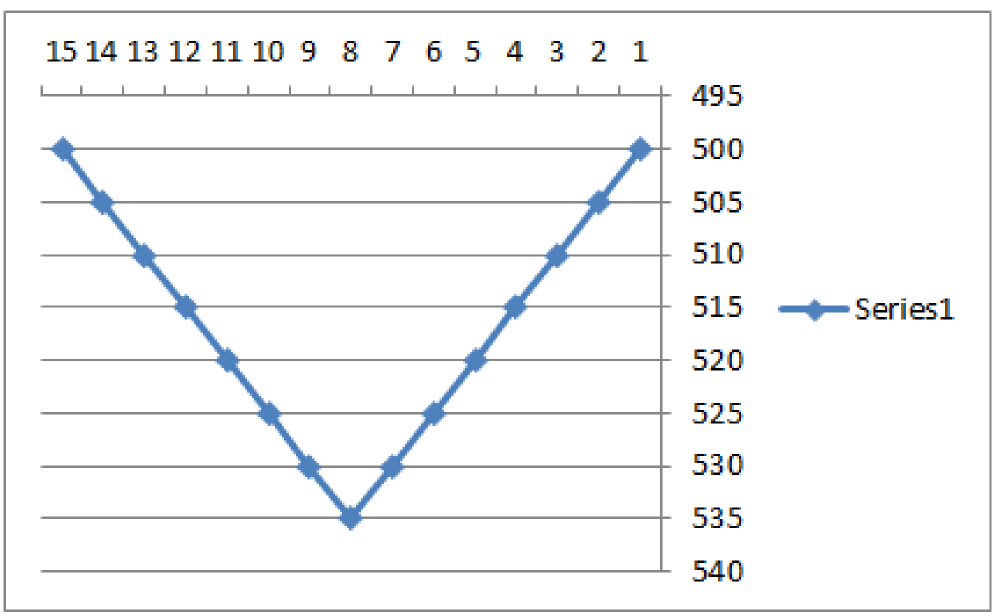

Fig.55 Results we would expect from the crotch height sensor

However an example of the results in reality are those shown below

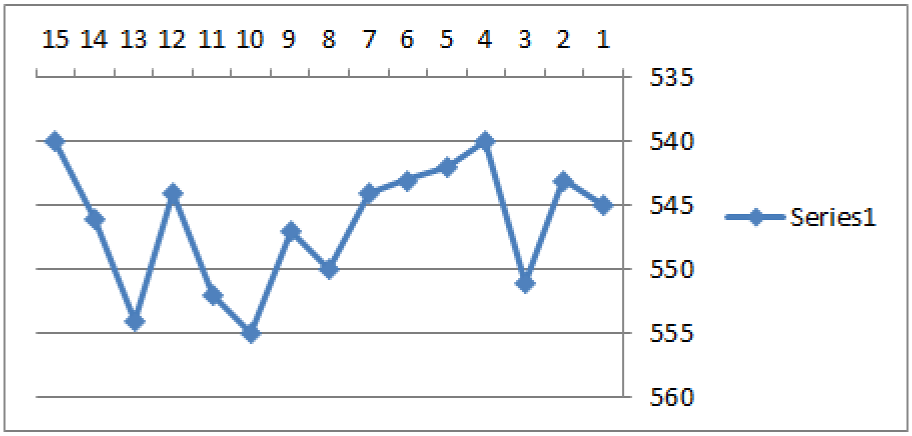

Fig.56 Actual results received back from the crotch height sensor.

These readings can be attributed to:

- Varying shades of white fat on the carcass
- Varying shades of red meat on the carcass
- Movement of the carcass
- Damaged surface material of the carcass (EG: fat/meat ripped away due to the hide puller operation
- “Foreign” meat/fat in the area of sensing that is not consistently found on an average carcass. An example of this would be a penis laying in the area of the crutch that is sensed, and thus giving our sensors and an incorrect measurement of “sensor to crutch distance”

These readings are not providing reliable enough data to consistently position the cutting tool to make an effective cut. It is felt that this issue could be resolved by incorporating the use of 3D vision which has developed significantly since the initial trials were performed at the commencement of this project.

Inverted Bungs
Another issue being experienced during the trials conducted following installation was inversion of the bung being caused by the vacuum “turning the bung inside out”. When this happens, there is potential for the bung to contaminate the inside of the carcass.

Stabilisation conveyor
Work is still required to eliminate dripping of water onto the carcass and production of aerosols from the stabilisation conveyor. MAR will work with Pro Ali to resolve these issues including:

- Modifications to the conveyor to move the wash tank away from the carcasses
- Installation of an exhaust fan to remove the aerosols
- Installation of air knives to dry the belt

- Installation of a ‘high top’ belt to move the carcass further away from the frame of the conveyor.

Sterilisation routine
Additional jets need to be added to the wash tank and the wash sequence modified to wash the tool more thoroughly and eliminate dripping of water onto the carcass.

Cycle time concern due to increase in chain speed
Moving forward GMP plan to increase their chain speed to around 10 carcasses/min. MAR are concerned that at this speed cut quality and tool sterilisation will be compromised.

5 Success in Achieving Objectives

MAR has developed an Automated bung cutting system that, provided it is accurately placed over the bung area, will successfully cut and free the bung. There have however, over the length of the project, been challenges. Many of which have been overcome however there are still a number outstanding including:

- Sensing required for accurate tool location
- Inverted bungs caused by the high vacuum
- Cross contamination caused by the stabilisation conveyor
- Quality of tool sterilisation
- Cycle time concerns with increased carcass rate.

Discussion of these challenges has occurred both internally within MAR and between MAR and GMP. The outcomes of these discussions are detailed in the next section of this report.

6 Conclusions and Recommendations

Discussions were held between Clyde Campbell (MAR) and Will Barton (GMP) with regards to the concerns highlighted in the previous section. Both parties are eager for the Bung Cutting project to succeed, however GMP have asked for a guarantee that if further work was to be carried out on the project that all the issues listed above could be resolved. In addition to resolving these issues the system would need to be capable of processing a higher carcass rate of approximately 10 carcasses/min, as GMP increase their output in the near future.

Discussions were held internally at MAR and while it was felt that MAR was comfortable with the fact that the issues above could be resolved, the concern was that of maintaining cut quality and tool cleanliness at a rate of 10 carcasses/min with the stock variation that is processed through GMP. MAR believe that the system could be successful in a plant that runs at a slower carcass rate and processes a more consistent size and breed of carcass, however it is felt that the best course of action would be to halt any further work on the system at GMP.