AUSTRALIAN MEAT PROCESSOR CORPORATION

Concept for the Automated French Dressing of Lamb Ribs

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1.0 Background

This project was approved by the Australian Meat Processors Corporation Ltd (AMPC) to create a practical and cost-effective machine concept for the automated French dressing of lamb ribs. The current process being used is a manual one, entailing operators using a knife to cut and to scrape the meat off the ribs in each rack, and thus resulting in a high labour content and cost for its preparation.

The Stage 1 of the Project therefore had an objective to create effective and practical machine concepts, carry out bench testing to prove the concepts, and as Stage 2, based onto successful testing, to create a practical automated machine design(s), estimated performance parameters and a budget cost for a production machine(s). Also, a proposal is to be forwarded for the next prototyping stage.

2.0 Concept Requirements

Our concept is to deploy a pair of shape conforming scrapers – one from the top and another from the bottom of the rib to contact and encompass the bone surface - and then by pulling this scraper pair from the root of the bone to its distal end, to “de-sock” the meat off each bone.

This would be a sequential process that would progress along the rack to treat each bone one at a time.

Thus concept is thus analogous to that of a wire stripper in the removal of the plastic cable insulation off the metallic conductor.

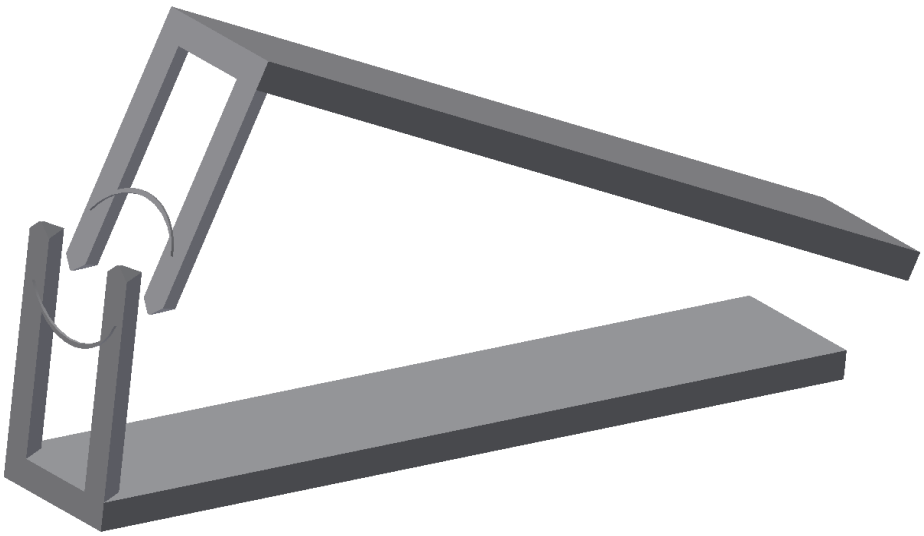

Figure 1: Shape Conforming Scraper

Fig 1 shows the general mechanical concept of the shape conforming scraper.

On each the top and bottom "U" holder is attached a flexible cutting means that would, when pressed down through the meat and over the bone, would conform to the shape of that half of the bone, respectively.

The “U” shaped holders are then drawn forward along the bone from its entry plane at the bone’s root to its distal end, scraping/cutting off the meat at its interface plane with the bone.

The upper and lower "U"s are staggered so that the bone is completely encompassed.

The bottom ends of the “U” arms are sharpened so it can be plunged through the meat between the bones, and the leading edge of the “U” arms are sharpened so that as the “U” shaped holder is drawn along the bone, these sharpened arms will cut through the meat in between the ribs.

From inspection of rib rack samples, it seems possible to common size the “U” holder to fit over all the rib sizes within the rack. In any case, if at the smaller end of the rack where the ribs are a little smaller and therefore pitched a little closer together, the “U” shaped holder can be simply twisted to insert the “U” arms over a narrower rib bone.

3.0 Actual Experimentation

The initial concept proposed the use of a thin and highly “bendable” fret saw blade as the flexible cutting means. This saw blade would be highly bendable to conform to the shape of the upper bone half when pushed down over it with the flat surface of the fret saw blade pressing, but without cutting, onto the bone surface. The so positioned fret saw blade would then be driven reciprocally to create a sawing

- action as it is drawn along the length of the bone - cutting through the meat, but sliding over the bone surface. The density difference between meat and bone would maintain the saw blade at the meat/bone interface surface as it was drawn down the bone half.
- as on a vibratory sand or cutting tool where the vibration amplitude of about +/- 2 degrees, is driven at say 1000 rpm.

Once we started to design such a device for testing, it became obvious that a thin, highly bendable saw blade was not a readily available off-the-shelf part.

Conventional scroll (or fret) saw blades which are miniaturised band-saw type blades, or the omni-directional cutting diamond coated wire types were far too stiff to allow bending to conform to the shape of the bone half. Even the thinner traditional Chinese sawing wire, see Fig 2, is not sufficiently flexible to conform to the shape of the bone half.

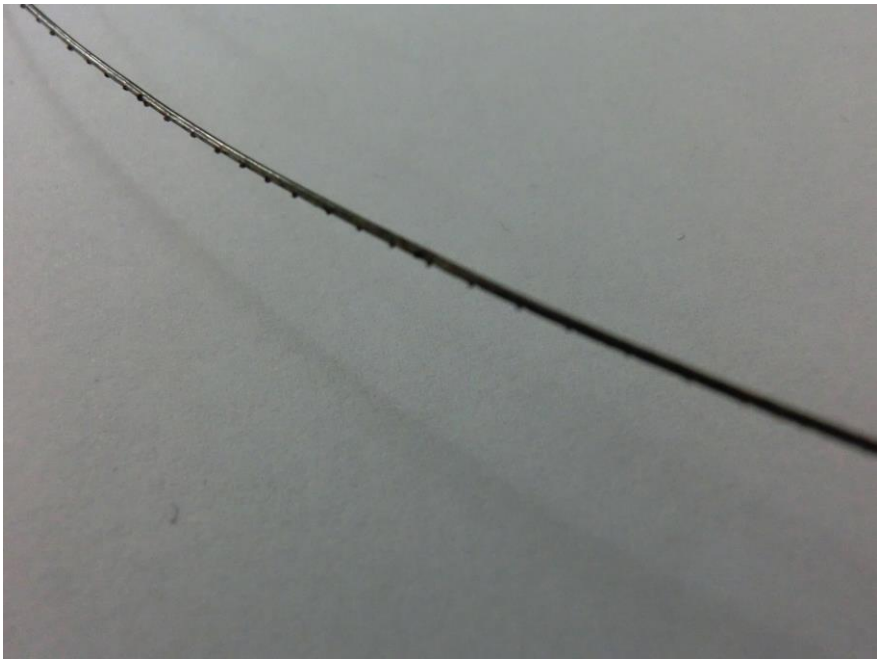

Figure 2: Traditional Chinese sawing wire

However, these cutters were able to be used by hand to scrape a section (from 11 o'clock to 1 o'clock, rather than the desired 9 o'clock to 3 o'clock due to its limited flexibility) of the meat off the bone. Using this tool, it would be necessary to employ multiple overlapping scraping paths to clean the entire bone surface, see Fig 3.

It was also found that the bone surface ***was*** damaged by the band-saw and the diamond coated wire, in that there were abrasion and scrape marks on the bone surface. To some extent this may be acceptable as the scrape marks were no worse than that evident in manually prepared French dressed rib available at the butcher shop.

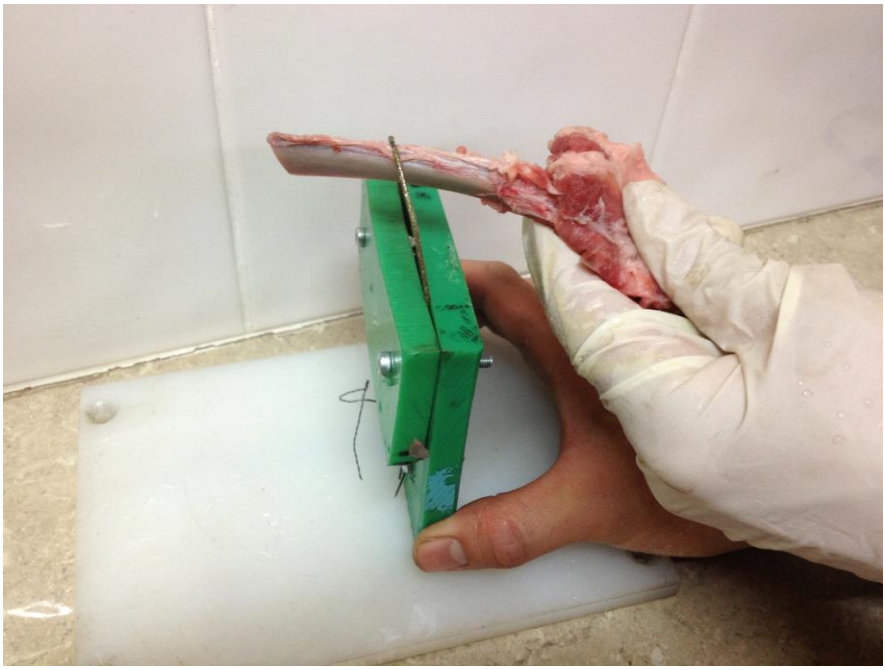

Figure 3: Diamond Wire testing

In pursuit of a scraping/cutting action that would avoid such scrape marks we experimented with a plain high strength plastic coated wire (plastic coated, multi-strand high strength and fine diameter wire used as a trace on fishing lines. We used an 80lb tensile strength, 0.5mm outer diameter trace wire).

This trace wire was mounted between the arms of a “U” shaped holder as prescribed in our concept, see Fig 1.

Due to the trace wire not having a sharp cutting edge, it cannot easily cut meat (without a very high force as used in garroting!), so we had to knife-cut an entry slit along the rack (top and bottom) in the plane dividing where the meat was to be left intact and where it was to be cleaned off. This slit was use as the entry valleys for the “U” holders. The knife-cuts also ensured a clean demarcation line between the meat and the cleaned bones at the top and bottom of the Frenched rack, thus giving the French dressed rack a neat appearance.

Fig 4 shows such a trace wire “U” holder. There are two such "U"holders mounted so when clamped into engagement with a rib it clasped the top and bottom of the same rib, like a wire stripper. The lower “U holder is fixed mounted, while the upper “U” holder is pivot mounted, and forced downwards onto the bone by hand.

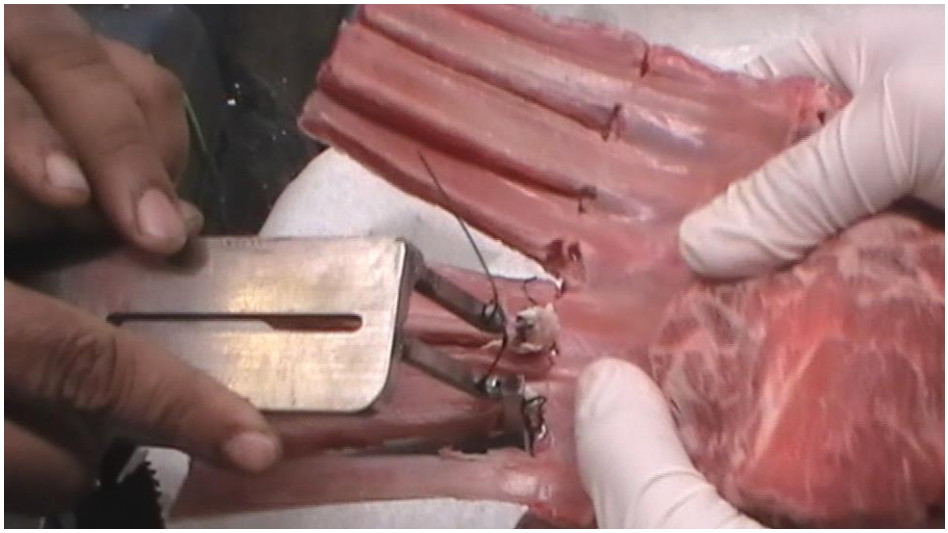

Figure 4: U holders with trace wire

A rib would be inserted between the opened “U” holders at the pre-cut top and bottom slits, the top “U” holder is pushed down to clamp onto the rib bone. Now the bone (attached to the rack) is pulled away from the clamped “U” holders to “de-sock” a tube of meat around that bone.

Fig 5 shows the inserted rib clamped between the upper and lower “U” holders.

Fig 6 shows the rack in mid-pull, with the meat being scraped off.

Fig 7 shows the rib after de-socking.

Fig 8 is a close-up view of the bone surface showing no surface abrasion or damage.

In the above tests, the rack was pre-slit top and bottom in the cleaning plane using a knife, as mentioned.

In these tests, we also made slits in the meat between each rib, but this is seen to be unnecessary when the leading edges of the “U” holder are themselves sharpened into knife edges.

Attached is a video showing the above test.

The video also shows a few strands of meat fibre still attached to the ends of each bone following its extraction from between the clamped “U” holders. These strands can be removed by inserting the rack ends between a pair of contra-rotating brushes (of food grade rubber fingers) to carry out a final cleaning.

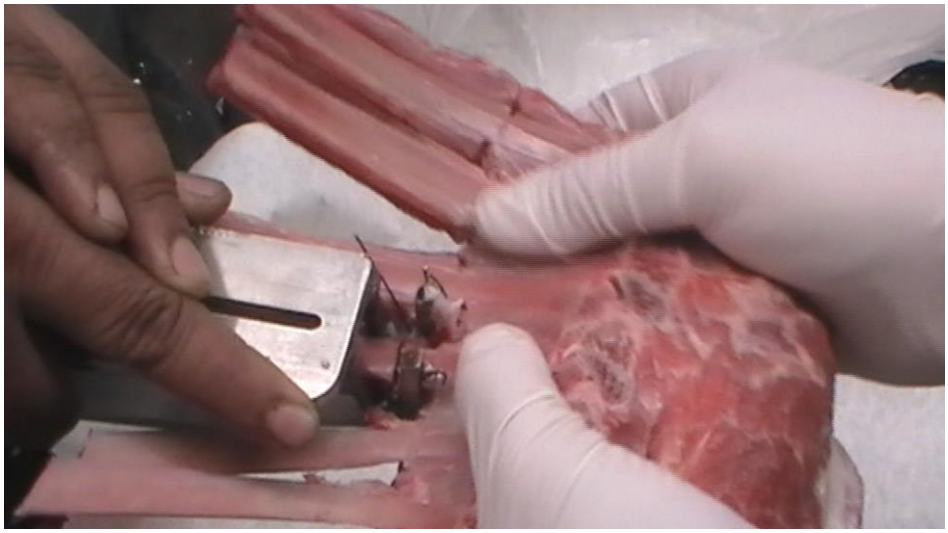

Figure 5: Rib clamped in U holders

Figure 6: Rib mid-pull

Figure 7: Rib meat with pulled off bone

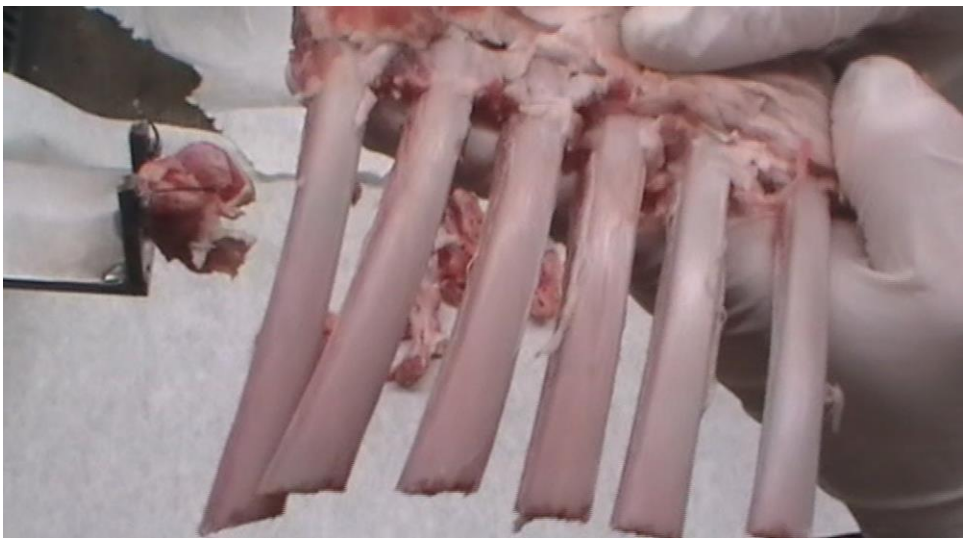

Figure 8: Rib Inspection with no abrasions or damage.

4.0 Useful Machine Options

We can see the tested concept being implemented in three different ways, as a

- Hand tool for occasional use (as in a butcher shop and even in a domestic kitchen)
- Bench-mounted mechanised tool as a low-cost efficiency improvement tool (again in a butcher shop or for low-volume production in an abattoir), and
- Fully automated Robotic Cell.

5.0 The French Dressing Hand tool

Here we see the basic concept implemented in the form of a large “wire-stripper”.

This is basically a pair of hand tongs with the trace wire “U” holders incorporated into the upper and lower jaws.

In operation, the rack of ribs is prepared by knife slitting along the top and bottom of the rack in the cleaning demarcation plane. Then, the tongs are applied sequentially to each rib in the manner of a wire-stripper to “de-sock” the meat around each rib.

Fig 1 shows a pair of such French Dressing Tongs.

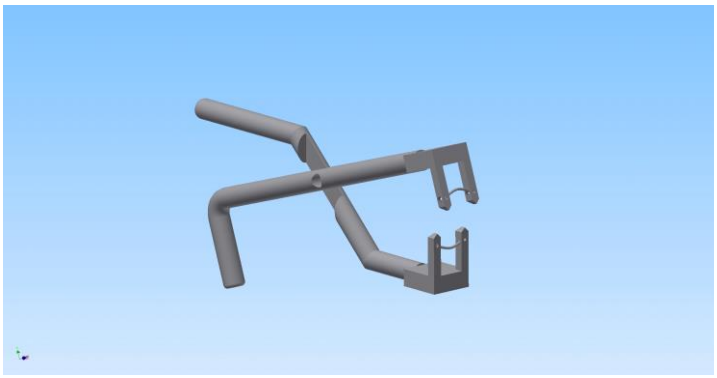

Figure 1. French Dressing Tongs

Both the upper and lower handles mount the trace wire “U” holders, which together form the clamping jaws for the tongs.

In operation, the rack of ribs is held in one hand, while the tongs are held in and manipulated with the other hand. The upper handle is pushed down by the thumb to apply the clamping pressure around the bone – note that the tongs will self-centre onto the clamped rib, whilst the bottom handle with its return is gripped by the rest of the hand for applying sufficient pull to effect the de-socking action.

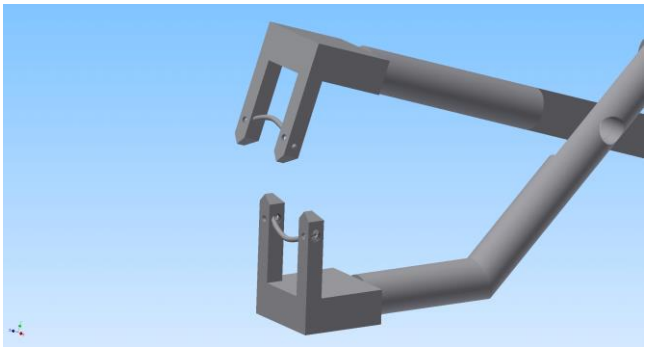

Figure 2. "U" holder

Fig 2 shows the details of the “U” holders which incorporates sharp points at the ends of the “U” to easily enter into the meat on each side of the bone, and knife edges on the leading edges of the “U” is slit the meat between the bones as the tongs are pulled down the length of each bone.

The identical trace wire that is attached between the legs of each upper and lower “U” is knobbed at each end, fits into and is retained by opposing keyhole slots machined in the legs of the “U”. Thus, replacement trace wires can be easily replaced by the operator (from packets of spares).

The budget cost to design and prototype in stainless steel is around $15,000, with an estimated production cost of say $800, in a production batch of 50 units. All cost estimates are budget and without GST.

6.0 The French Dressing Bench

At the next level up in efficiency of use, the French Dressing Bench implements the French Dressing Tongs in a manner suitable for better ergonomics and for higher production usage.

The general concept of the Bench mounts the Dressing Tongs fixed to a bench, so that in operation, the operator holds the rack of ribs by its meaty end with both hands, facing the actual rib rack outwards.

The operator then, inserts each rib in turn into the opened jaws of the tongs, clamp the jaws down onto that rib using a foot-treadle, and pulls the rack of ribs away from the tongs to de-sock the meat off each rib.

Basically, this is a modified version of the “U” holders wherein its handles are now bench mounted at an ergonomic height and are sprung opened. The lower handle and its “U” is fix mounted, while the upper handle and its “U” is pivoted and sprung in the open position as shown in Fig 3.

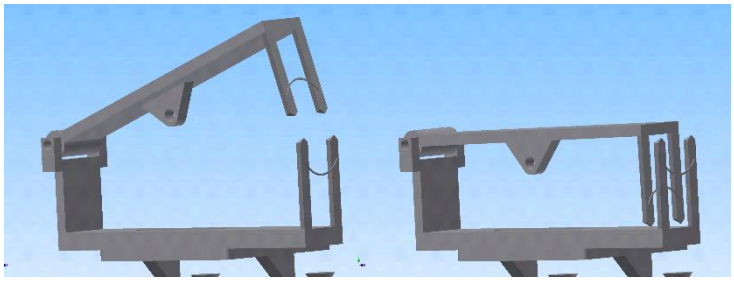

Figure 3. Spring opened "U" holders

The upper handle is attached by a linkage to a foot treadle for actuation i.e. pushing down on the foot treadle to clamp the rib. This foot operated version avoids the needs to special guarding that would otherwise by required for a tool that is power-assisted.

Alternatively, a foot operated pneumatic trigger can be used to activate a pneumatic cylinder to do the clamping, but this would require a higher level of guarding. The advantage of using a pneumatic cylinder for clamping is the clamping pressure can be adjusted and set to a constant force (and not have the clamping force reliant on the operator's foot pressure).

Fig 4 shows the French Dressing Bench.

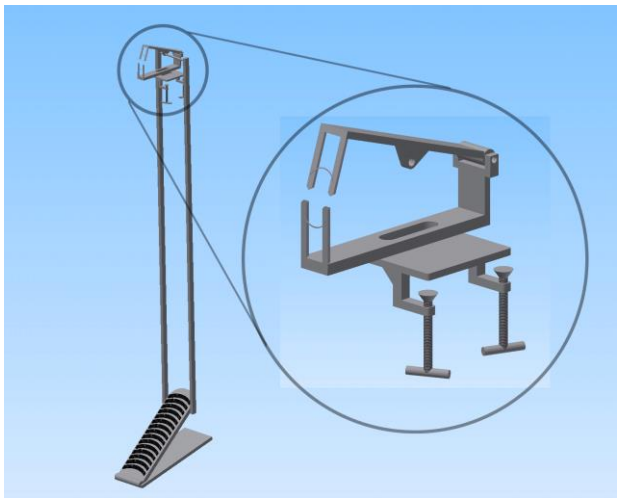

Figure 4. Bench Mounted French Dressing Machine

In operation, the rack would be prepared by knife slitting along the top and bottom of the rack in the cleaning demarcation plane.

Each rack would be picked by hand and each rib positioned in turn into the “U” holder jaws, foot treadle clamped, and the rack drawn outwards to de-sock each rib. After all the ribs have been de-socked, a little hand cleaning to remove any adhering meat strands may be required to finish the rack.

We estimate that with practice, that each rib may be de-sock in 2 seconds.

The budget cost to design and prototype in stainless steel around $22,000, with an estimated production price of say $1,500 when produced in a batch of 25 units. All cost estimates are budget and without GST.

7.0 The French Dressing Robot Cell

This section addresses a fully automated System wherein racks or ribs can be buffer loaded in batches into the Robot Cell's infeed module, and the dressed racks are outfed into a bin or conveyor.

The operations in between are fully automated, using a robot for the handling functions, and a Vision System to provide the imaging of each rack.

For full automated operation we will need the following functions:

- A batch input means for multiple racks. This will be a buffer conveyor or a compartmented infeed tray in which each rack of ribs is orientated in a consistent manner for the robot to pick-up.
- A Vision System to detect the exact position and orientation of each rack for:
  - robot pick-up and
  - determine the location of each rib along the rack for top and bottom slit cutting the along the cleaning demarcation plane, and
    - to locate the position of each individual rib for loading into the U clamp for de-socking the meat.
- A robot with a gripper that is able to grip and hold a rib rack by its meaty end (in all its varying sizes),
- A top and bottom set of spring loaded knives to which the robot can pass the gripped rack to make the slit cuts above and below the ribs in the cleaning demarcation plane.
- A set of automatic clamping top and bottom “U” holders, with clamping force control. Some means of removing the meat sock halves from each “U” holder will be necessary after every rack to avoid build-up of meat here.

- A set of post de-socking clamping grippers to “brush-off” any meat strands still adhering to the rib bone ends.
- An output conveyor or bin or chute.
- Australian Standards safety guarding.
- An Operator Interface Panel.

To address the cleaning of the stripping wires, and to ensure a fast production rate, it may be necessary to implement the “U” holder tool as a twin-headed module wherein while one head is in operation, the second head is being cleaned of meat debris. Such a twin-headed module is shown in Fig 5. The removal of meat off the trace-wire is by counter-blowing the meat strips by directed air-blasts.

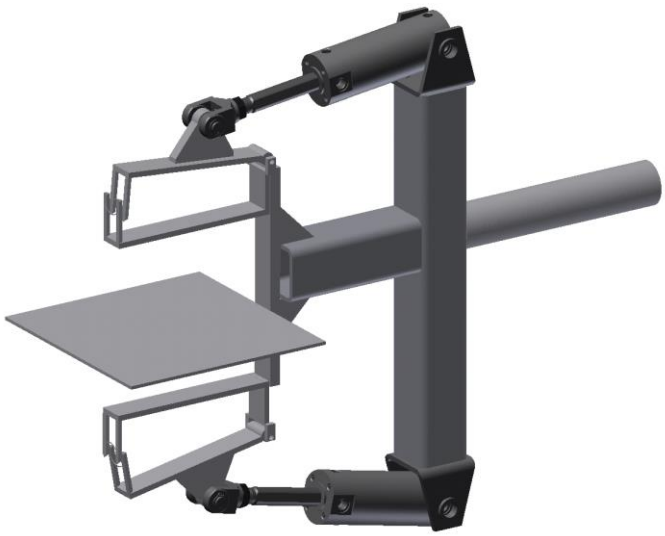

Figure 5. Twin-headed "U" Holder tool for meat desocking

Fig 6 shows a close-up view of the proposal universal Ribs Rack robot gripper. The gripper must engage and clamp the meaty end of the rack and be clear of the “cleaning plane”, and it must be able to clamp and hold the range of rib rack sizes expected to be processed. An important requirement of the robot gripper is that once the rack is “settled” into the gripper that the rack is not able to shift around during the sequence of operations.

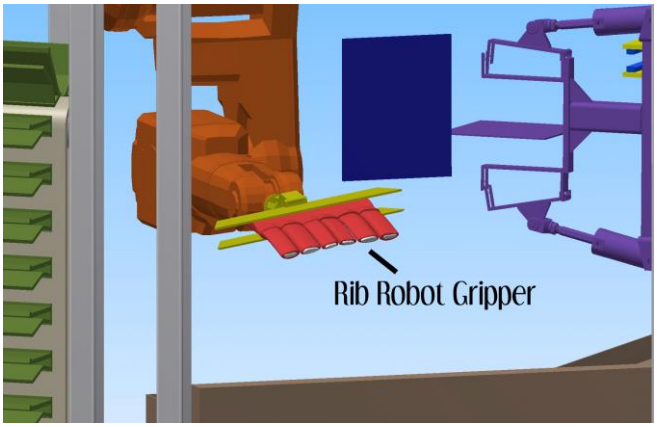

Figure 6. Rib Robot Gripper holding a fresh rack

Fig 7 shows a candidate solution for the racks infeed buffering module. To save space here we have a vertical conveyor onto which the racks can be manually loaded between light clamp plates. The robot will pick off the racks one at a time on the opposite side of the vertical conveyor.

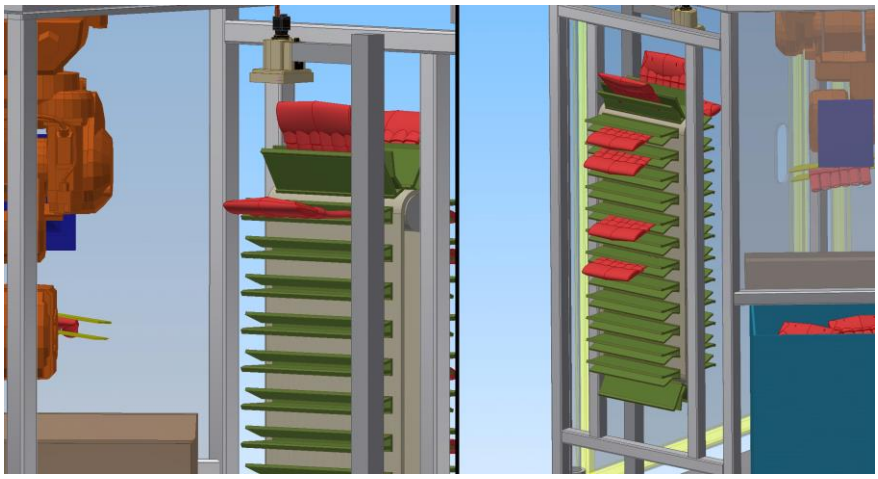

Figure 7. Vertical Rack Infeed Conveyer Inside(left) and Outside(right).

The Vision System (see Fig 8) will be positioned here to “see” the incoming rack so that the robot can precisely grip it without its gripper intruding into the cleaning plane.

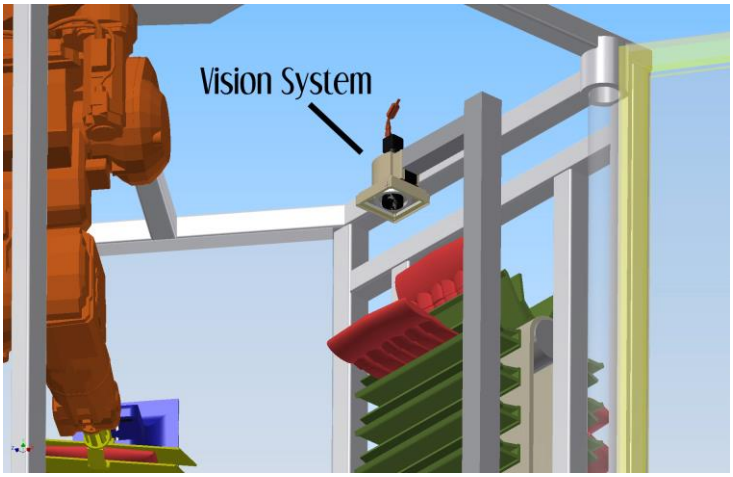

Figure 8. Vision System Positioned above rib rack for picking and analysis.

Following pick-up and clamping of the rack in the robot gripper, the rack will be passed between an upper and lower sprung knife blades that will create the top and bottom slits in the meat in the cleaning demarcation plane. Since the rack will be re-imaged by the Vision System directly after pick-up, the robot will be able to position the gripped rack into the slitting knives to obtain the ideal slitting location. See Fig 9.

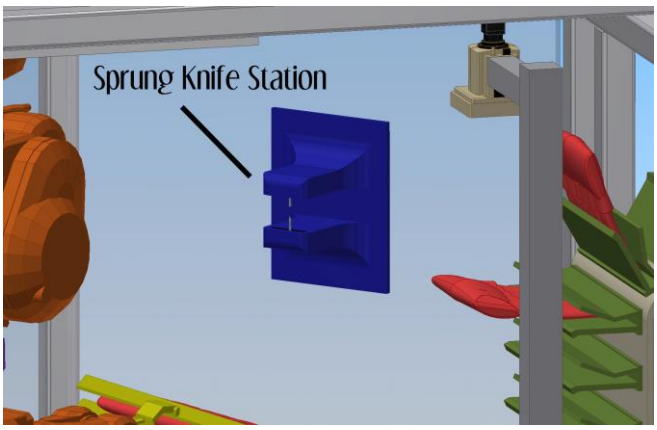

Figure 9. Sprung Knife Blade Station for creating top and bottom slits.

After the above slitting operation, the rack will “settle” in the gripper in a certain stable position. It is this “settled position” with respect to the robot gripper, that the second Vision System camera is used to detect the positions of the individual ribs. This data will then allow the robot to position each rib in the “U” holders, up to the cleaning plane and to de-sock it.

After de-socking, the rack may still need a little cleaning to remove meat strands adhering on the distal ends of the bones. This cleaning can be carried out by stripping clamps (or something similar). See Fig 10.

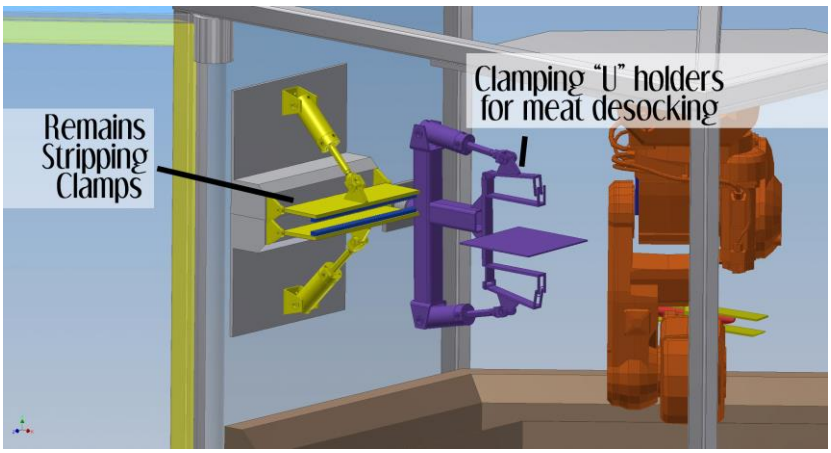

Figure 10. Clamping "U" holders and Stripping clamps for final meat desocking and stripping.

Following this the rack is released into a collection bin as shown in Fig 11 below.

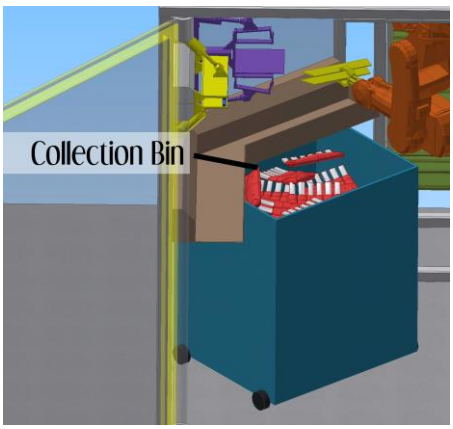

Figure 11. Rack Collection Bin

Figs 12, 13, and 14 show different overall views of the Rib Rack French Dressing Robot Cell. Note that the Cell is guarded to Australian Standard AS4024.

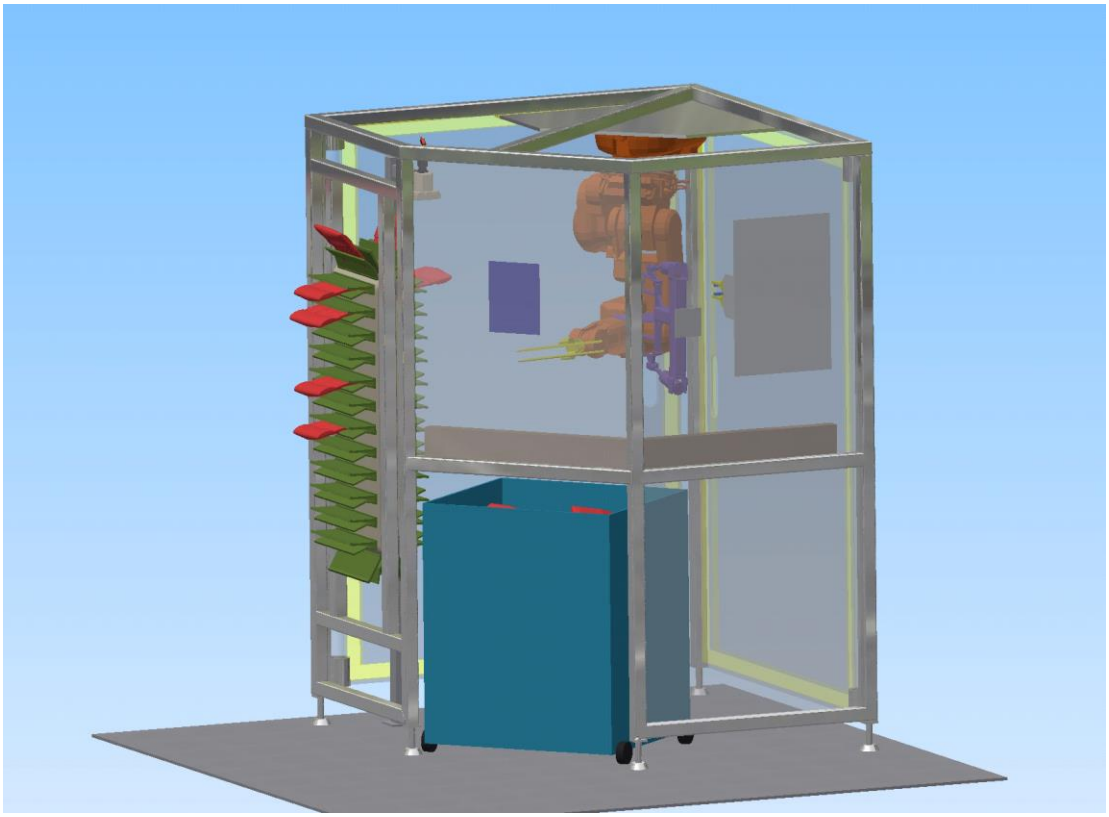

Figure 12. French Dressing Cell Front View

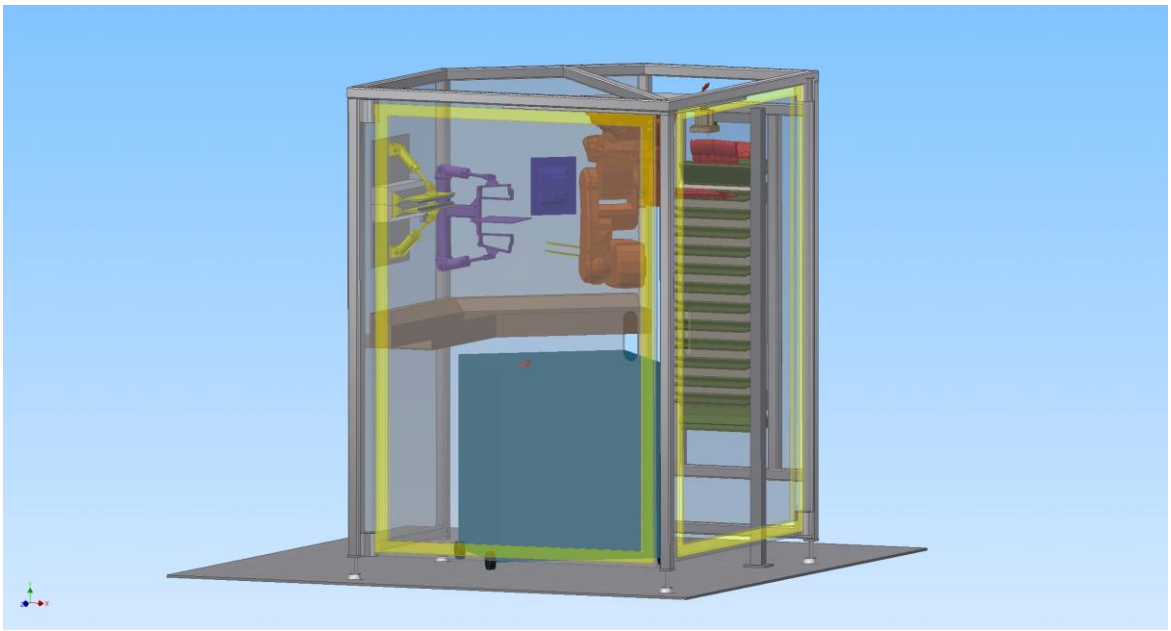

Figure 13. French Dressing Cell in operation

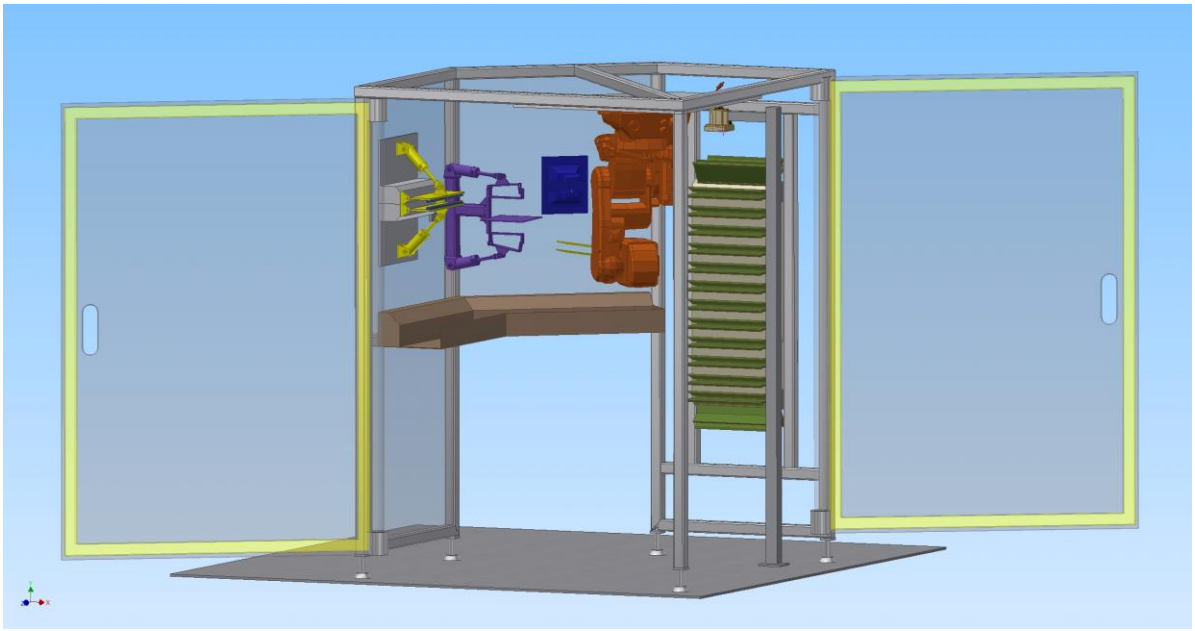

Figure 14. French Dressing Cell open for cleaning

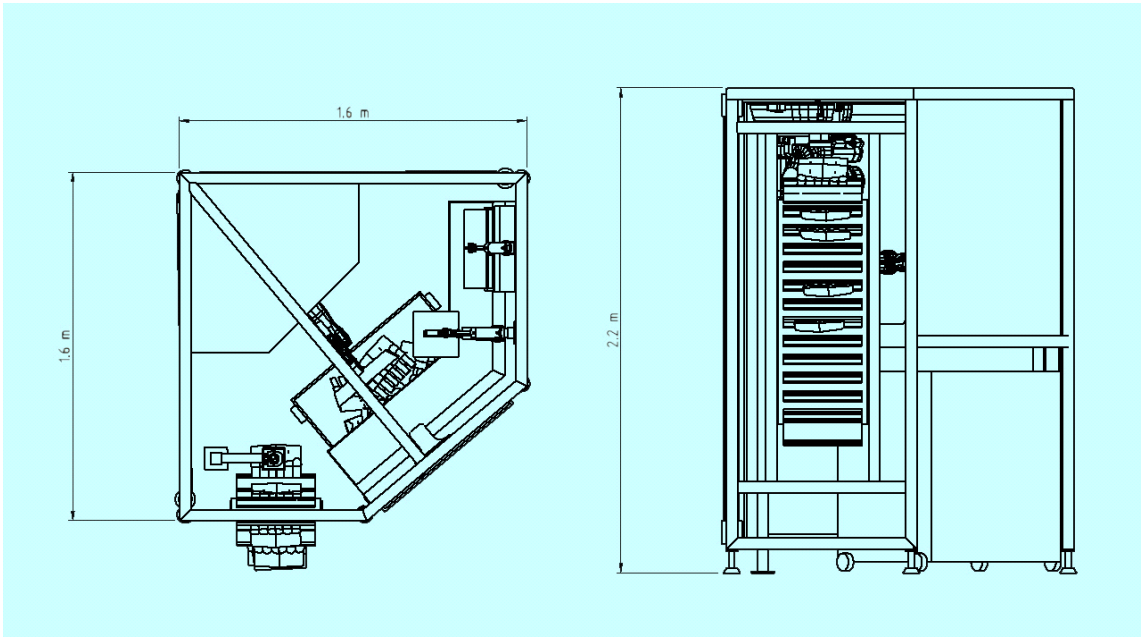

Figure 15. Estimate of overall dimensions.

Fig 15 shows the plan view layout of the robot Cell and the approximate foot-print it will occupy.

It is estimated that the Robot cell will be able to French Dress between 2 and 3 rib racks per minute.

The estimated cost of the above described Robot Cell Prototype is $260,000, with a repeat Robot Cell estimated at $120,000. All cost estimates are budget and without GST.

9.0 Expert Panel Feedback

The immediate next step was a meeting with AMPC representatives to review and to discuss the findings of this Stage 2 Report, before we proceed to the development of a specific concept in Stage 3).

Following the tabling of the above Stage 1 Report, we indeed received the opportunity to bounce the included ideas off a panel of Abattoir Technology Managers, during an AMPC R&D Steering committee meeting in North Sydney (3rd December, 2014).

Basically, the consensus view from the Abattoir Sector's perspective, was that there was indeed good potential for an effective automated method for the French Dressing of Lamb Rib Racks in the abattoir, but for commercial feasibility it would need to achieve a faster throughput rate, better than or at least equal to the current 30 seconds for an entire rib rack (120 racks per hour), and as there are now between 3 to 4 operators/shift engaged in this function, ideally the Robot Cell should target around 10 to 12 seconds per rack. Also the robot Cell must be cost-effective on a labour replacement basis.

It was suggested that it would be seen as desirable to be able to de-sock an entire rack (compressing 8 to 9 ribs) in a single operation.

10.0 Next Step

We concur that this desired level of performance, in the employment of a bank of up to 9 "de-socking" heads, was desirable and we propose that conceptually it would be achievable in practice.

Following further discussions with the AMPC, it was agreed that the next step was a further **Implementation Planning Stage**, in which a

- multiple de-socking head module was explored
- the bulk loading of multiple lamb racks, i.e. a buffer for the infeed stock, was explored in conjunction with potential users to arrive at a practical system that dove-tailed with the needs of the abattoir(s).
- the resulting Robot Cell would be modeled for performance at a more refined level to give a more certain projected production rate.
- The resulting Robot Cell would be modeled and designs carried out at a refined level to give a more certain projected Prototype and Production Robot Cell costing.
- This would be carried out in close consultation with, and visits to, an abattoir partner to ensure that the final outcome was a practical solution.

Applied Robotics await the formalisation of this Next Step.

Following the completion of this **Implementation Planning Stage** the AMPC and its industry participant(s) would review its findings and determine whether or not to recommend the design and development of a Prototype Robot Cell.

11.0 Fact Sheet

CONCEPT FOR THE AUTOMATED FRENCH DRESSING OF LAMB RIBS

The current process for the French Dressing of Lamb Rib Racks is a manual one, entailing operators using a knife to cut and to scrape the meat off the ribs in each rack, and thus resulting in a high labour content and cost for its preparation. It now takes around 30 seconds to manually “dress” each rack, and there are 3 to 4 operators per shift engaged in this activity.

This R&D Project therefore had an objective to create effective and practical machine concepts to automate this process, to carry out bench testing to prove the concepts, and as Stage 2, based onto successful testing, to create a practical automated machine design(s), estimated performance parameters and a budget cost for a production machine(s).

A simple concept was created for the automation of this task. This concept is based on that now used to strip the plastic insulation off an electrical cable, i.e. a wire-stripper, with the addition of the ability of the meat stripping device to conform to the size and shape of the bone as it strips the meat from along the length of each of the shape and dimension variable rib.

Successful bench testing has been carried out to develop and to verify the technical feasibility of this method.

Furthermore, implementation concepts have been created at 3 levels, as a

- Hand-tool for occasional use (as in a butcher shop and even in a domestic kitchen)
- Bench-mounted mechanised tool as a low-cost efficiency improvement tool (again in a butcher shop or for low-volume production in an abattoir), and
- Fully automated Robotic Cell.

Following consultation with a panel of Abattoir Technology Managers, the consensus view from the Abattoir Sector's perspective, was that there was indeed good potential for an effective Robot Cell for the French Dressing of Lamb Rib Racks in the abattoir, but for commercial feasibility it would need to achieve a faster throughput rate, say an entire rib rack in around 10 seconds (360 racks per hour), and be cost-effective on a labour replacement basis.

It was suggested that it would be seen as desirable to be able to de-sock an entire rack (compressing 8 to 9 ribs) in a single operation.

The benefits of such a Robot Cell, if practical and cost effective, would be

- Labour reduction
- Production Rate of around 360 Frenched Racks/hour;
- OH&S - Elimination of dangerous operational practices;
- Quality improvements in the cleanliness and reduction of scrape marks on the cleaned ribs;
- Processing efficiencies - accuracy of cuts reduce need for rework;

- Food safety - reduced contamination compared to manual operations;
- Reliability and accuracy.