final report

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HookAssist development

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Abstract

In an effort to address OHS and labor issues in the meat industry, the red meat processing sector is committed to investigating the development of a cobot (intelligent assist) technology. Industry approved the development of manual assist technology for a number of reasons. These devices are seen as part of the strategy for addressing a number of threatening issues in the meat processing industry including high injury and turnover rates. Theoretically the development and implementation of manual assist devices such as cobots into the meat processing industry will reduce the force and labor requirements of tasks, thus allowing a greater variability in the people that are employed in all tasks. The tasks will become safer and the industry as a whole will be seen as more appealing given the perceived innovation and advancement in the industry.

This report documents the development of the HookAssist, a novel intelligent human-assist device that improves the ergonomics of manual meat processing operations beyond any that are available commercially.

Executive summary

This project was to develop a novel human-assist device that improves the ergonomics of manual meat processing operations beyond any that are available commercially. Specifically to build a fully functional assist device that reduces the forces required by the operators hook hand and encourages better operator posture during manual beef boning operations.

Kinea Design designed and fabricated a fully functional testbed device for assisting the hook hand in manual beef boning operations. The device will be used in a test location and then, with improvements, will be installed in a production facility.

The device will be a testbed, in the sense that it will allow beef boners, researchers, ergonomists, and Kinea Design engineers to perform functional tests of a variety of different applications and thereby be able to optimize the design for a production device. It will therefore possibly have more versatility than will probably in the end be required.

This project was conducted in 3 phases.

Phase 1 – made measurements in plants, and mocked-up non-functional assist devices, to determine the range of motion of the assist device that was needed for the required tasks, in order to determine how to integrate it into existing plant structures, and to assure that its geometry will not interfere with work flow or traffic in the plants.

Phase 2 – fabricated a fully functional experience prototype assist device. The prototype device was used in a non-production testing environment. It was over-designed, so that it can serve as a test-bed, allowing a number of investigations and variations to be explored.

Phase 3 – with the lessons learned from phase 2, Kinea Design iterated on the design and built an assist device for plant installation and in-production testing.

The HookAssist is currently being tested at a JBS Swift plant in Brooklyn, VIC, AU, performing the tasks that it was designed to assist, including: thin skirt, tenderloin, loin, h-bone, rump, knuckle, topside, silverside, shank. The device is also being used to explore other beef processing operations that might be enabled by the HookAssist.

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1 Background

Cobot is a term coined in the 1990's by Professors Edward Colgate and Michael Peshkin of Northwestern University: A Cobot is defined to be a robot for direct physical interaction with a human operator, within a shared workspace. The term is derived from "collaborative robot", and indicates that cobots are designed to interact very closely with human operators. This is in stark contrast to the typical use of modern industrial robots, where fully automated tasks are undertaken with very little human intervention. According to the strict technical definition, a cobot is a passive device. That is, artificial forces introduced are strictly resistive and do not do work. Any active forces must be applied by the operator. MLA and AMPC initiated the process two years ago to adapt develop assisted systems for the red meat industry based in this Cobotic principle.

In 2005 a review of current technologies and technology providers was undertaken and it was determined:

1. currently there is no cobotic technology that is applicable or available to the meat industry
2. there are a few research centers around the world that are capable of undertaking work in this area.

Phase 1 of the project included a weeklong visit by the researchers to processing sites, observing the boning process and consulting with industry representatives. A clear two year plan was mapped out and expectations and outcomes agreed upon. This stage delivered clear outcomes and defined a clear 2 year plan from the process of research to onsite installation.

In February 2007 Michael Peshkin and Edward Colgate visited MLA and industry facilities in Brisbane and Sydney, following up our earlier broad tour at a Cargill plant in Colorado.

During their visit they had opportunities to observe an Australian boning operation (at Teys Bros.), and to receive some training and hands-on experience in boning with the help of an experienced boner and trainer, Greg Butler.

They met with engineers, innovators, managers, and suppliers to the industry. With many of these we were able to hear their thoughts about what forms of automation or assistance are promising, what's been tried, and what challenges we face. In particular they benefited greatly from the open workshop and discussion at MLA on February 8, 2007.

2 Project objectives

The overarching goal of this project was to fabricate a fully functional testbed device for assisting the hook hand in manual beef boning operations.

The objectives listed by phase include:

- Phase 1
    - Establish preliminary requirements

        - make measurements/observations in plants, and mock-up experience prototypes, to identify the performance, integration, human factor, workflow issues, etc…

- Phase 2
    - Fabricate a fully functional assist device.
    - Fabricate a non-production testbed, that would allow researchers, ergonomists, and Kinea Design engineers to perform functional tests and thereby inform the design for a production prototype.
- Phase 3
    - Test HookAssist experience prototype (developed in Phase 2) in a controlled environment in a beef processing plant in Australia.
    - With the lessons learned from phase 2, design and fabricate an assist device for plant installation and in-production testing.
        - Particular attention will be focused on:
            - hook handle, length, and profile , gimbal geometry, gimbal self-homing, increase in pull force capability, ceiling mounting, chain tracking, hook-meat release, conversion to 415V-3phase power, waterproofing, serviceability, reliability, safety.

3 Methodology

The development was structured in the following manner:

3.1 Phase 1

MLA and AMPC with the permission of the AMPC technical committee engaged an Australian based university to conduct a literature review of all possible solution providers and developments in the area of cobotics. The outcome of which was the identification of Northwestern University (NWU) in Chicago, IL, which was selected and engaged to develop a first prototype through its spin-off company, Kinea Design.

3.2 Phase 2

During the first three month of Phase 2 Kinea Design developed, built and demonstrated two prototype systems. The two prototypes were kinematically different, one was a cable based device, and the second one was a rigid-arm based device. They were both a 1 active degree-of-freedom mechanism that would apply forces in the vertical direction.

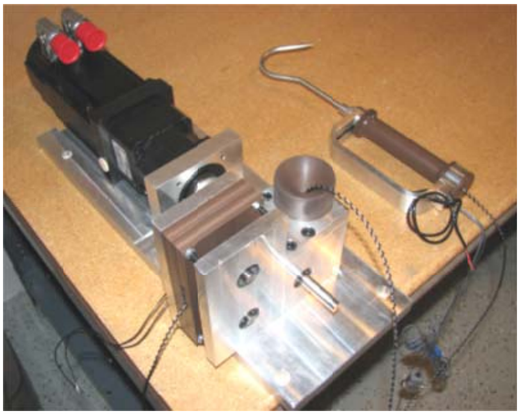
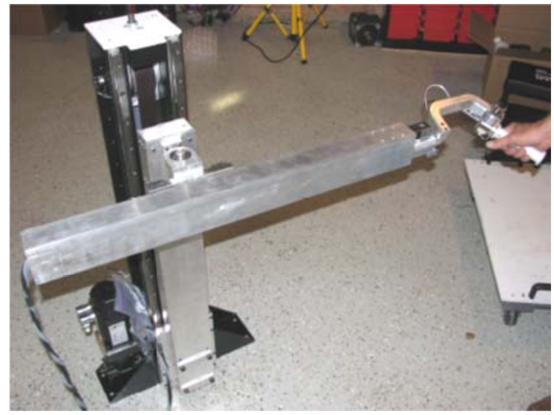

Figure 1 – (left) Picture of cable based HookAssist prototype. (right) Picture of the 'rigid arm' based HookAssist prototype.

In October 2007, a demonstration of both devices was carried out at Kinea Design's facility in Evanston, IL. The lessons learned from this demonstration will be taken into account during the second half of this phase.


Figure 2 – Picture of a John Hughes performing a boning operation on a hind quarter using the (left) rigid-arm prototype and the (right) cable based prototype.

3.3 Phase 3

Phase 3 started by having a number of different beef boners test the HookAssist experience prototype developed during Phase 2 in a controlled environment in a plant (i.e. not on the production line) performing the tasks that it was designed to assist with. These include a range of boning operations, such as thin skirt, tenderloin, loin, h-bone, rump, knuckle, topside, silverside, shank.

Once the HookAssist was tested Kinea Design together with MLA and industry experts refined the set of requirements for the next prototype HookAssist with the lessons learned and any other additional requirements that arise. These requirements in turn guided the design and development of a HookAssist that is flexible enough to operate in a beef processing plant.

Following the design phase of the Kinea Design fabricated one HookAssist device and installed it at the JBS Swift plant in Brooklyn, VIC, for in-production line testing. It is expected that this testing will further guide the design of a durable final product.

4 Results and discussion

4.1 Phase 1 Results & Discussions:

4.1.1 Regarding Ergonomics

Many joints. Our own perception in a day of training, and the opinions of others, is that potentially damaging stresses occur in both arms, at all three joints. (And possibly back as well.) We were not able to obtain medical statistics, and even if these were available they would be confounded by the variety of jobs that boners rotate through.

We observed dramatic changes of posture during the boning operations. Some postures favored production of forces by the knife hand and some by the hook hand. Both medical/epidemiological and force/ergonomic studies would be very valuable, to better understand the origin of stresses and how workers compensate.

Throwing. It is common for workers to throw heavy pieces of meat. The large impulse forces needed to do this may be a contributor to ergonomic injury.

Pain balancing. In the absence of rigorous studies, we are operating under the working hypothesis that boners compensate by variations of posture, and by variations of how much force is exerted with each hand, in such a way as to balance the stress on their joints.

Whether stress on different joints is "pain balanced" is an important question. If it is true, the consequence is that an assistive device that reduces the force needed from one arm, will also greatly benefit the other arm, because the load can then be shifted to make best use of the machine, and posture can be chosen optimally for the unassisted arm too. If it is false, then the benefit will be more confined to the arm that is assisted.

Additional information and recommendations on ergonomic issues pertaining to beef boning applications are described in Biomechanics of Boning a Hind Beef Quarter, by Dr. Gary Dennis [1], and will be taken into consideration during development.

4.1.2 Regarding Knifesmanship & worker acceptance

An important cultural aspect is the relationship of the worker to the knife. Boning is a skilled job and it is clear that boners take pride in skill with tools, and especially with the knife. Not only is it a matter of pride, but also the worker's dexterity with the knife is highly developed, as is his ability to feel through the action of the knife as if it were an extension of his arm.

In the introduction of new technology, we can expect skepticism. It may be possible to design assistive devices for the either hand, but the standard that workers will demand for "transparency" (quick, responsive operation with the ability to feel through the device), will be much higher for the knife hand, than it will be for the hook hand. From an engineering perspective too, the hook hand is technically easier, since fewer axes of motion and slower speeds are needed.

4.1.3 Regarding High value operations

Boning operations are high-value, high-skill, and productivity-sensitive. High bodily stress is commonplace and an ongoing problem. Three particular operations in boning as particular good initial targets:

- aitch boning,
- knuckle pulling, and
- topside.

These are currently manual operations, though some semi-automation has been studied.

4.1.4 Regarding Yield & Productivity

The prospects in both yield and speed look very good for a well-designed assist device.

The report titled *Update on Manual Assisted Project Developments (13th November 2007)* [2] showed improvements in yield (for knuckle pulling and aitch boning) with a mechanized pull-down device over manual operation.

This result holds out great hope. It suggests that the force levels now in use, which are limited by the capability of the boner, may be less than ideal for yield. Another possibility is that the postural adaptations needed to produce a large pulling force cause the worker to be less able to see or cut for greatest yield.

Speed was not discussed in [2]. However, we may find that with a highly responsive hook-hand assist, both yield and speed can be improved.

4.1.5 Design Direction

For the reasons above -- presumed benefit to both arms by assisting either one, and higher transparency demands on knife assistance -- we come to the conclusion that our first target should be to assist the hook hand.

This is the same conclusion that has guided several other manual assist projects.

Previous technical approaches, however, have been limited by available technology to hook-only. They cannot accommodate the needs for highly intuitive user control, or many axes of motion, that knife assistance would require.

The "cobotic" approach to manual assistance that we can develop may be extended to the greater demands of knife assistance. Nevertheless, the way to gain credibility with workers and management is to start with the less ambitious target and demonstrate the benefits.

4.1.5.1 Resulting preliminary requirements for a first boning assist device

1. It must fit into an existing plant, without major modifications. Some fixation will be needed to floor or wall, etc. Electrical power will be needed.
2. It must fit into existing workflow, ideally assisting one current operation with minimal adjustment needed to adjacent operations.

3. It must not reduce yield or speed. Must not damage or contaminate product.
4. The space required along the chain should not be greater than the worker-to-worker spacing at present. (We are also considering mechanisms that can follow along the chain, over the length of several workspaces.)
5. It must be rugged, able to withstand washdown, and minimally susceptible to damage from impact, excessive force, knife cuts, or other abuse.
6. Must be able to comply with food safety requirements, for instance cleaning of the hook between carcasses when required.
7. It should be possible to revert to unassisted (manual) operation without interrupting the workflow.

4.1.5.2 *Resulting preliminary Safety requirements*

Safety is a paramount concern and must be addressed at every stage of design. We have previous experience in a similar context, that of assist devices for automobile assembly. In that case safety required a combination of careful engineering choices (e.g. speed and force limits, attention to pinch points); good user-interface and communication between man and machine; training of workers, managers, and installers; and the drafting of appropriate regulatory guidelines.

We expect many of the same needs in the present context.

4.1.5.3 *Resulting requirements for technology transfer*

1. Intellectual property rights must be established so that the Australian red meat industry benefits from its investment. IP is currently under discussion to allow an agreement to be documented for the next phase of work.
2. The appropriate local industry, probably the automation industry, should be involved in the project. We have made some contacts for this purpose.
3. Local engineers should be trained, ideally starting during phase 2. We have discussed involving engineers in Australia and New Zealand in project development.
4. We have also discussed placing an Australian engineering student with us at Northwestern University for a period of time.
5. Local industry should ideally become the manufacturer, or at least the system integrator, for assist devices.

4.2 Phase 2 Results & Discussions:

In August 2008, a demonstration of the HookAssist device was carried out at the Northern Melbourne Institute of TAFE, (Epping campus) to Australian beef and sheep processors and producers (Figure 3). During this week at NMIT the device tried by a number of different boners as well as administrators, and industry experts. The device was used to perform the complete set of cuts on both hind and forequarters of a number of beef carcasses, as well as some boning tasks on sheep carcasses. The device proved to be flexible enough to carry out all the tasks that were tried, these included: tenderloin, skirt, loin, aitch bone, rump, knuckle, chuck, topside, silverside, brisket, flank, among others (for one task it was determined that a subsequent device should have more pull force).


Figure 3 – (left) Picture of the HookAssist as installed at NMIT during the August 2008 Workshop. (right) Boner demonstrating use of the device.

Following the demonstrations round-table meetings were carried out to discuss and capture the audience's thoughts, concerns, comments, and suggestions for a subsequent design.

4.2.1 General HookAssist Requirements resulting from Phase 2

4.2.1.1 <u>Design gimbal structure so that it does not interfere (collide) with the user's hand/wrist.</u>

Summary: During the demo it became clear that the Hookassist gimbals interfered with the user during a pull as the gimbals descended below elbow height. The interference was with the back of the wrist, imparting a torsion in the YZ plane which subsequently increased the downward pressure on the user intent sensor. This created a positive feedback loop during which the device behaved in a non-intuitive manner and a painful pressure on the wrist required the operator to adopt a very non-ergonomic posture in order to continue with the pull.

Workshop Comments:

- One of the joints of the gimbal stands in the way of the wrist and the boner keeps hitting it. Place that joint/axis out of the way
- Sometimes the gimbal seemed to be jammed and could not be brought backwards. As this problem seemed to happen when moving the arm at its lowest position it could be a combination of the system being too low and one of the joints of the gimbal standing in the way of the boner's wrist. Both problems have been highlighted already.

4.2.1.2 Design the gimbal handle shape to facilitate hook control, meat release, and minimize grip-slip

Summary: The handle of the gimbals would slip in the grip of the operator, reducing their ability to control the positioning of the hook. The handle was round and covered with bicycle grip tape.

Workshop Comments:

- “Need different size handles (for mesh gloves, etc…)”
- “Color coded possibly to match mesh gloves)”
- “Need non slip grip”
- “The grip/handle should be hand shaped so that it does not slide or slip on the hand when applying some force on it.”
- The gimbals handle should have an ovoid section. Possibly thermoformed like some existing hooks. Possibly with a knurled / sharkskin type surface.
- “Round handle makes it hard to release the meat after the cut has been made” (and the fact that the handle is in the center of rotation of the gimbal).

4.2.1.3 Device shall tolerate washdown and avoid harboring bacteria, and contaminating product

Summary: The device should not affect the quality of the product. One aspect of this is cleanliness. The device will be washed with high-pressure spray at least daily. The washing is often done by a contracted crew that will not be trained in any of the specifics of the device. The outer casing of the device must satisfy two core requirements: it must protect the inner workings from water damage; it must not have any hidden external surfaces that would be missed in a washdown. Also, the device must not contaminate the product with lubricants or particles.

Workshop Comments:

- “Need to seal and protect from condensate. Plants use 120°C water.”
- “Use positive pressure, dip sensors in plastic”
- “75 – 90 °C water for wash down”
- ““accordion” cover has too many nooks and crannies”
- “Have disposable/reusable covers”

4.2.1.4 Increase the pull force of the device as much as possible without compromising the transparency of the device (the goals is to reach 330 lbf pull force).

Summary: During some cuts operators were able to max out the pull force, and were actually leaning on the device trying to get more ‘pull’ out of the device.

Workshop Comments:

- Pull force needs to increase to 330 lbf (he measured 578 lbf when pulling a cut straight off)
- More power/grunt
    - o “100 lbf is too little”
    - o “Boners use their body weight to pull the h-bone”
    - o “limit the force based on the type of cut being performed, type of beef (old vs young too)”

4.2.1.5 Device shall be able to be installed either on the floor or ceiling (overhead structure)

Summary: The present approach can be mounted either on the floor or in the ceiling. It is envisioned that the final device will be easily changed for use by left and right handed people.

Workshop Comments:

- “two designs – top mounted and bottom mounted. Lefty/righty capability is down on the list of priorities.”
- “Lefty/Righty also needs to be able to address directionality of chain”
- People would not want to dramatically change the boning room to fit the machine
- Mount the system in an overhead rig or gantry
- “Upside down mounting may be preferable, less contamination.”

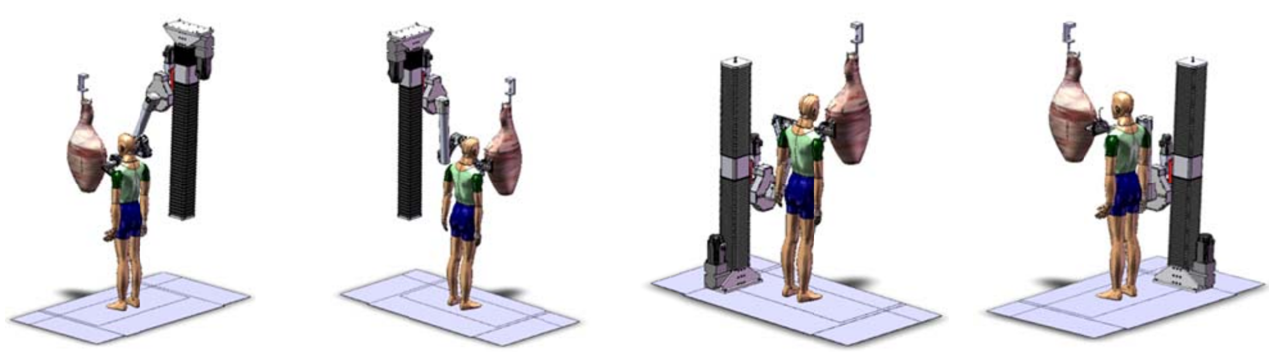

Figure 4 - Illustrations of the four different possible configurations that will be possible with the device. From left-to-right the configurations are: floor-right handed, floor-left handed, ceiling[1]-right handed, ceiling-left handed.

4.2.1.6 Device shall safely address entanglement issues with the chain

Summary: The chain moves under separate control. It's possible that the chain will attempt to pull a carcass further down the line with the hook caught in the carcass or even on the chain

[1] Ceiling structure or strong back.

itself. The desired failure in this case is for the hook to pull away from the gimbals without damaging the gimbals so that a simple hook replacement is all that is needed to get the line up and running again.

Workshop comment:

- “Need mechanical fuse in case the hook is caught on the chain.”
- “Chain never stops in a plant”

4.2.1.7 Implement safeguards until a Hazards Assessment performed as per the Robotic Industries Association’s BSR/T15.1 draft standard for Intelligent Assist Devices – Personnel Safety Requirements reflects a “tolerable”[2] level of risk.

Summary: Industrial robotics have traditionally been regulated such that safety is achieved by keeping people out of the workspace. This device however, is an intelligent assist device therefore we will use as guidance the RIA’s BSR/T15.1 draft standard for IADs.

Workshop Comments:

- “Need to clarify the standards under which this equipment falls.”
- “What about union acceptance issues?
    - “no problem with unions – the device helps the worker.”

4.2.1.8 Design the gimbal to return to a “home” orientation when released by operator

Summary: Once the handle is released the gimbal can swing into an awkward orientation making it cumbersome to “untangle” back into the proper ‘home’ orientation.

Workshop Comments:

Gimbal getting into weird orientations between operations. Hook sticking out into the space of operation.

4.2.1.9 Implement an electro-mechanical interface that allows for experimenting with different end effectors?

Summary: Alternate uses of the hook-assist device were discussed at the demo. While many ideas were put on the table, the general consensus was to focus on boning operations. Within the context of boning, ideas of alternate ways of manipulating the work were discussed. The most common idea was to try a gripper or pincher end-effector. Should we create a standard interface between the hook-assist arm and the gimbals such that other end effectors can be tested?

Workshop Comments:

[2] Determining “tolerable” will vary by user or organization, and is a subjective value of acceptance of potential harm.

- "Gripping functionality. It would be helpful to have the possibility to properly grab a piece of meat, move it and transfer it where it needs to be and release the grip to place it in location (another station where further processing will be performed for instance)"
- "Not only a hook but also a gripper/pincher solution might be helpful"
- "Design and build several interchangeable gimbals with different hook configurations (like different hook shapes, double hook, etc) and a gimbal with gripping functionality"

4.2.1.10 <u>Reassess the device's ROM from gathered data</u>

Summary: The workspace of the Hookassist device was guided by the study performed by Gary Dennis. During the demo it was observed that there was not enough -Z range of motion available. Some of these observations were during the experimentation with what types of cuts could be made. Some of the observations were made at Harvey beef where the rail was lower than what was expected during design.

Workshop comments:

- One person felt there needed to be more forward and backward workspace available. However, he did not use the device much. The boners regularly ran out of backward workspace but it's my opinion this is because the had run out of vertical workspace (due to the low rail) and were trying to continue pulling long rib cuts.
- "We don't need so much backward workspace."
- He had an idea to put a bar across the leg to keep the carcass from coming with the hook.
- Need to restrict the meat form swinging forward, toward the boner, during a pull. Need a bar that restricts its backward movement. The may dramatically reduce the required ROM.
- Horizontal ROM should be equivalent to the size of a "station", 5-6 feet
- The main joint is too low, and the boner is forced to lean down to perform some operations. Place the system higher, the boner at a lower level or raise the rail so that the meat hangs higher (this comment was made by the boner trying the system who happens to be a tall guy. All that said it seems the result would be better by implementing this suggestion as similar feedback was heard in the first workshop in Melbourne)
- One person suggested offsetting the gimbals 20cm forward of the rest of the lamp-arm to keep the lamp-arm from hitting product on the rail. I think this is a good thing to investigate.
- "Moving chain situation presents a ROM problem for a fixed device – should travel with the chain"
- "Allow more flexibility and room to move to the boner by placing the robotic arm in front of the tower, while leaving the boner behind the tower."
- "Put the system on a swivel to cover the work area"

- “Boner had to change his posture because the robot arm was in his way – inverting it will solve this problem”

4.2.1.11 Implement a quick-release interface for the Hook such that boners can replace the hook with one of their own design, and/or be able to sterilize the hook easily and quickly if necessary.

Summary: It's common for boners to customize the shape of their hooks. There were several comments about details of the hook shape that affected how well it grabbed meat or let go of meat. The need for hook sterilization and for a mechanical fuse create a natural break in the design that would make this straightforward.

4.2.1.12 Design the Hook to have a shorter shank, a more ergonomic form factor, and facilitate meat removal

Summary: Operators had difficulty controlling the hook point accurately. Factors involved are learning to control the device in general, dealing with a 5kg virtual mass with no gravity cues, and the distance from the handle to the hook tip.

Workshop Comments:

- "Hook is too far away, needs to be shorter."
- "Increase the precision of hook insertion."
- “Shorter hook, hook is an extension of a boner’s hand”
- “Current hook is too long, meat gets stuck on it, it is difficult to separate the meat from the hook after the cut is finished”
- “Hook should be both shorter and have less of a “turn around””
- “Boning hook is far away from you hand – that may be responsible for some of the difficulty in fine motor control at the end of the hook”

4.2.1.13 Incorporate indicator lights for visually observing the operational state of the device

Summary: It needs to be clear what state of operation the device is in. It needs to be easy to change the state of the device to a safe one. The device will be shut down occasionally during shifts for break periods.

Workshop Comments:

- “Need a way to turn the robot off for break periods. Cork on hook? A place to hang the hook?”
- “Need indicator lights”
- “Green for “in” operation, Red for “not in operation””
- “Emergency stop”

4.2.1.14 Incorporate an easily accessible E-Stop switch

Summary: It needs to be easy to change the state of the device to a safe one. The device will be shut down occasionally during shifts for break periods.

Workshop Comments:

- "Need a way to turn the robot off for break periods. Cork on hook? A place to hang the hook?"
- "Emergency stop"

4.2.1.15 Implement a mechanical override

Summary: If the device stops working or if the product on the chain is temporarily processed in a different manner, we need to be able to use the area in front of the chain for other tasks. For these reasons we need the ability to fold the device out of the way such that it is in a configuration that is safe to work around.

4.2.1.16 Implement sensor data gathering capability

Summary: Ability to gather sensor data and faults will be implemented. For the Hookassist_0.2 device, two main categories of information will be collected. 1: Information that will inform Kinea Design in optimizing the production device motors, workspace, and strength to fit actual usage patterns. 2: Information that will allow identifying the causes of failures for rapid diagnostics and preventative maintenance scheduling.

4.2.1.17 Eliminate pinch points

Summary: Self descriptive

4.2.1.18 Devices input power requirements shall be changed to 3ph, 415 VAC (50 hz)

Summary: Self descriptive

4.2.1.19 Focus particular attention on reliability and serviceability

Summary: Actuators with proven track records in industrial applications will be used.

4.2.1.20 The hook (with handle) will NOT be detachable as a functional hook

Summary: In the HookAssist 0.1 device a manual hook was designed into the gimbals. The intent was to allow the boner to release the manual hook for separate use. Scenarios included: a desire for faster movement than the machine provided for sub-tasks like marking, removing the hook for sterilization. During the demo it was observed that a second manual hook would be easier to use and that hook sterilization was not as time critical as originally perceived.

Workshop comments:

No need for detachable hook

4.3 Phase 3 Results & Discussions:

Figure 5- Pictures of the HookAssist and its sub-assemblies.

During Phase 3 the design and fabrication of the HookAssist was carried out per the requirements established in Phase 2, see Figure 5. Some of the sub development tasks included the:

- development of an electronic "**node board**" - given the number of sensors and consequently wires and connections that exist throughout the device and the need for them to be hermetically sealed and protected inside the device, as well as reliability concerns Kinea Design developed a node board that consolidates local sensor signals on a common 4 conductor communication bus. This approach keeps the device smaller and increases reliability.
- development of a custom "**hand presence sensor**" - the existence of a satisfactory off-the-shelf solution was anticipated, but not found given the industry's aversion to push buttons, and requirements such as intuitive/ease of use, vandal proofing, sealing, etc. To address this Kinea Design developed a custom handle sensor (with no moving parts) that can detect when a person is touching it.
- development of two custom **position sensors** - typically off-the-shelf position sensors can be easily integrated, for this project however due to the requirement for redundant sensors that fit in small water tight spaces Kinea Design designed and contracted two custom potentiometers from vendors.
- development of a new **sealing technique** (for the tower) and the subsequent testing that was required - a simpler and inexpensive "bellows" solution that addressed the issues of the first prototype was initially anticipated but not approved. To address this Kinea Design developed a custom seamless sealing technique for the tower.

5 Conclusions and recommendations

Figure 6 – Picture of boner at the JBS Swift plant in Brooklyn, VIC, AU.

- HookAssist device was fabricated to the specified requirements and delivered.
- Device was installed and will be tested at the JBS Swift plant in Brooklyn, VIC (joint effort between KD & Scott).
- During the next 6-12 months
    - Yield studies will be performed.
    - More lesson's will be learned, requirements will be revised, and the
    - design will be iterated.
- Scott Technologies appointed global commercialisers.
- Patent for the HookAssist technology was submitted in Australia.

Kinea Design believes, and designed the HookAssist such that it could become a platform for addressing other industry needs by potentially simply replacing its end-effector, i.e. the hook for a gripper, etc… Kinea Design thus encourages the search for those other applications that could benefit from this technology.

6 Reference list

1. Dr. Gary Dennis; Biomechanics of Boning a Hind Beef Quarter; Ergosolutions Pty. Ltd.
2. Update on Manual Assisted Project Developments, November 13, 2007