final report

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Automated First Gambrel Transfer

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Automated First Gambrel Transfer

This is a report summarizing the work done on this project. It is organized around the milestones 1 through 6 of the subject contract. The problem turned out to be considerably more challenging than was originally conceived due to the constraints imposed by trying to make the solution compatible with a currently operating process line. Nevertheless, the work planned for Milestones 1 through 5 was completed in full.

One set of constraints that was not initially considered is embodied in several sets of guides that provide lateral support of the gambrels at stages of the process, such as hide pulling, when the gambrels are subjected to loads directed laterally to the direction of transport. As is explained below, because of these constraints it proved to be impractical to perform an in-plant demonstration as was originally envisaged for Milestone 6.

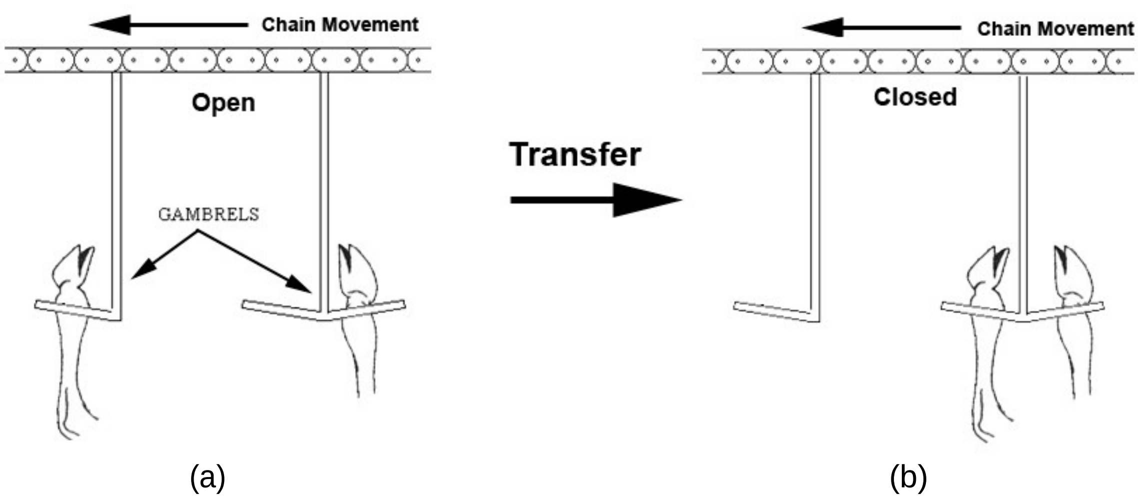


Figure 1: Transfer of the carcass rear leg hocks from the initial legs open position (a) to a legs closed position (b).

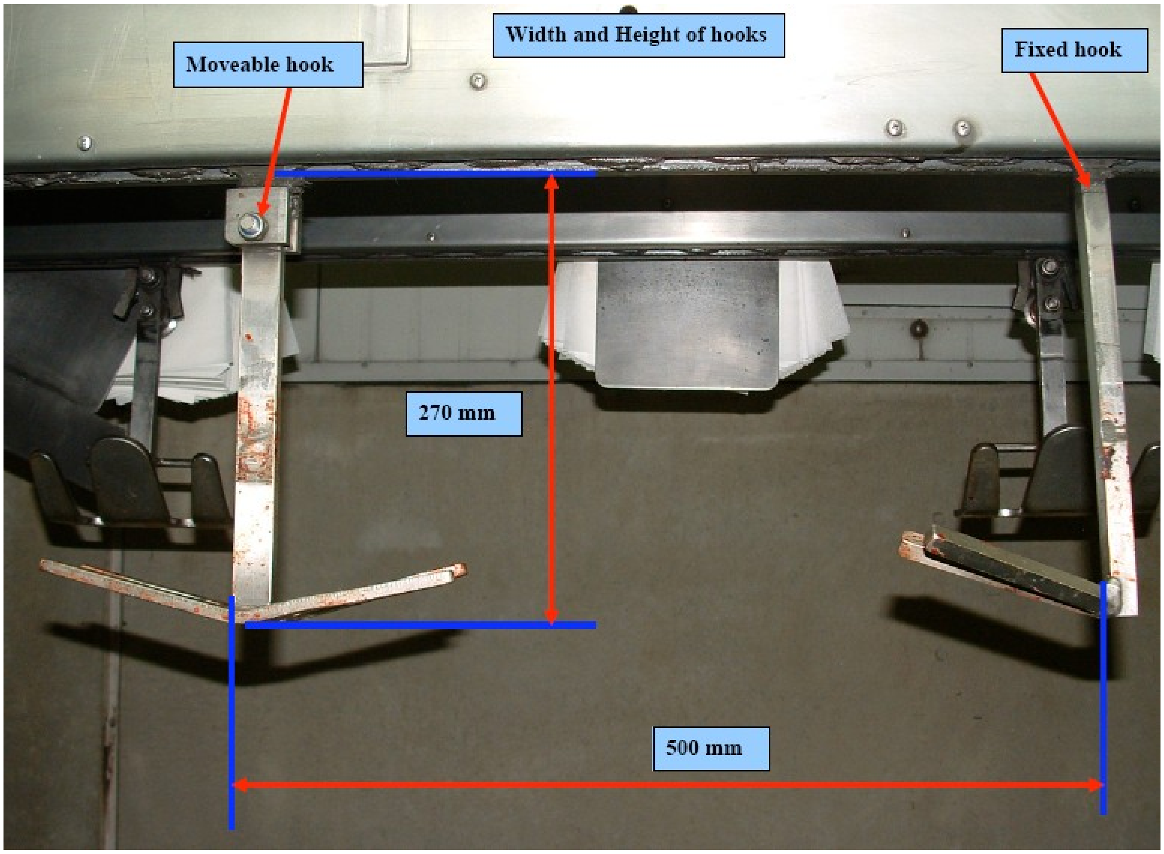


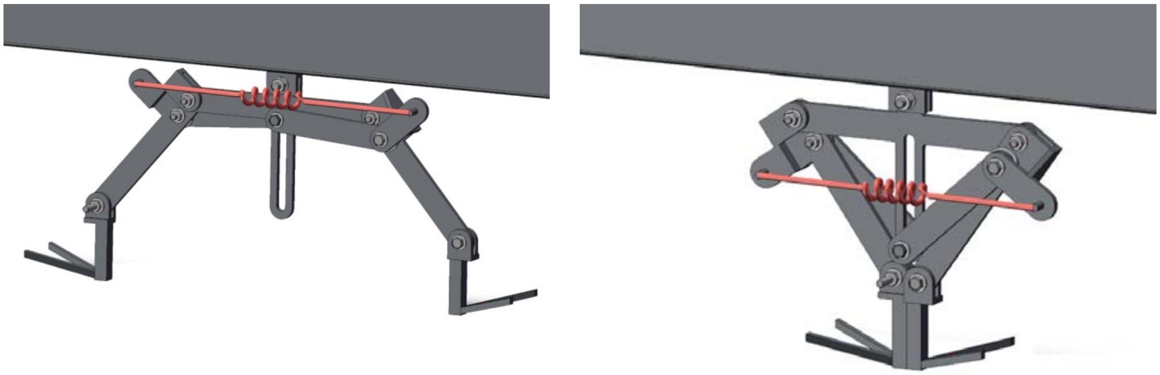
Figure 2: A view of the actual gambrels used in the CRF process, along with basic dimensions. The carcass is initially positioned with one leg in a single hook, and the other in the adjacent double hook. Later in the process it is re-positioned to have both hocks on the double hook, as shown in Figure 1.

The Problem:

During the processing of lamb carcasses in most plants, the carcass is initially supported by gambrel hooks suspended from the slaughterhouse conveyor. The carcass is initially suspended by placing the rear hocks into hooks that spread the legs apart approximately 500 mm. After the carcass has been eviscerated, the hocks are repositioned into a double hook so they are separated by only about 100 mm (Figures 1 and 2). Both the initial placement of the carcass into the gambrel hooks, and the subsequent re- positioning are manual operations requiring the full-time attention of one worker. The work is heavy, dirty and dull making these operations prime candidates for automation. However, it is the philosophy of this project that automating such operations does not necessarily require active mechanisms. We are seeking to automate the transfer of the carcass from the initial legs separated position into the legs closed position by means of a purely passive mechanism.

Although the product of this project is applicable to most lamb processing lines, we chose to use the CRF Colac Otway plant's process as an exemplar. The cooperation of

CRF personnel in providing detailed information about their process and line is much appreciated.



(a) (b)

Figure 3: The final design of prototype 1, as per David Neville. The two hooks are connected by a pair of links that are maintained in symmetric positions by a slide guiding the pin connecting them along a vertical path. Thus, they constitute a toggle locking the mechanism into the open position in (a). When the pin is pushed through the toggle position the tension spring (shown in orange) closes the mechanism.

Milestone 1: Mechanical design

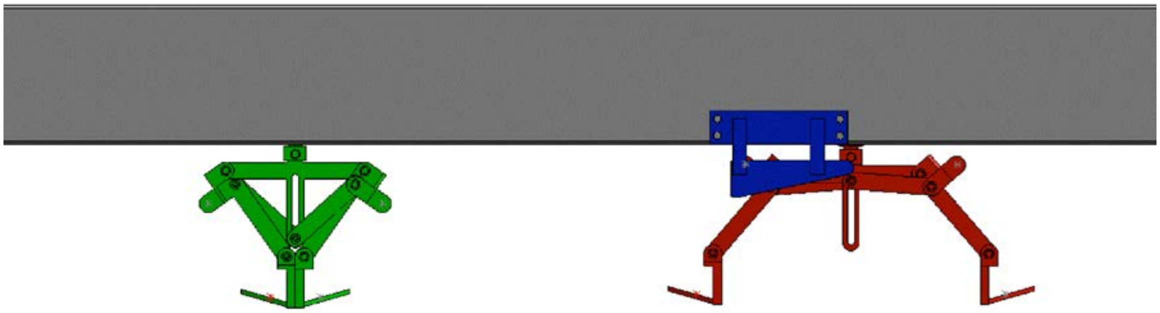
The first prototype was largely designed by Mr. David Neville, based on Professor Waldron's original idea, as a capstone (final year undergraduate) project. Mr. Neville's capstone thesis is included on the CD that accompanies this report. The prototype assembly is shown on Figure 3.

It is important to remember that the system includes not only the gambrel mechanism itself, but also ramps to trigger closing and reset of the gambrel mechanism actuated by the motion of the slaughterhouse conveyor. The initial concept to trigger closing of the mechanism is shown in Figure 4.

Milestone 2: Manufacture of prototype and design of test conveyor rig

The manufacture of the prototype of the gambrel mechanism was completed. Photographs are shown in Figures 5 and 6. After working with the prototype and bench testing it became apparent that, no matter where the force was applied a very large force was needed to reset the linkage to the open position. This was due to the placement of the joints in the mechanism providing very poor force transmission characteristics.

The original concept was for the major components of the test rig to be similar to those used on the CRF slaughterhouse conveyor, and for them to be purchased from an OEM. That proved not to be practicable necessitating design from scratch and construction of a rig to test tripping of the gambrel mechanism. This was done and is largely documented in the thesis of Mr. Ross Macpherson that is included on the



(a) (b)

Figure 4: Concept for triggering closing of the first prototype. The ramp shown in blue is fixed to the conveyor frame and engages a roller on the sliding pin axis of the mechanism. The motion of the conveyor causes the pin to be pushed down through the toggle position allowing the tension spring to close the mechanism.

accompanying CD. It was not possible to replicate the link chain of the CRF conveyor in the laboratory, and a rig employing a roller chain was used to drive the gambrel mechanism through the tripping stops to open and close the mechanism was designed and manufactured.

Figure 5: The first prototype shown in the open position.

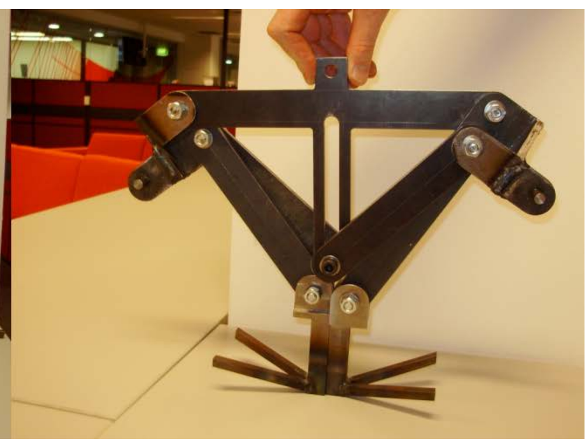


Figure 6: The first prototype shown in the closed position.

The original version of this rig was far too lightly constructed for it to be able to apply the forces necessary to trip and reset the mechanism. The light and flexible roller chain did not sufficiently constrain the path of the mechanism. Consequently, a major redesign and remounting of the rig was conducted. In particular, a tensioner was added and the chain was backed in regions where the mechanism would have loads applied to it. Guides were added to prevent the mechanism from falling out of the vertical plane, and to provide mounts for the tripping ramps. The final version is shown in Figure 7.

Figure 7: The final configuration of the test rig. The chain moves between the wooden constraining walls that also provide mounts for the tripping ramps. The positions of the tripping ramps are given by the double line of screws in the top right quarter of the wall, and the single line of screws in the bottom left corner.

Milestone 3: Integration of the gambrel mechanism with the conveyor rig.

The single gambrel hooks on the CRF chain conveyor are welded to the massive stainless steel chain links. The double hooks are pivoted from a bracket that is also welded to a chain conveyor link (Figure 2). The stability that results from this arrangement proved to be very difficult to duplicate on the laboratory rig. The gambrel mechanism was initially integrated with the chain using a bracket integral with one of the chain links. This is documented in Mr. Macpherson's thesis. This system, on its own does not provide adequate support for the mechanism when triggering and resetting. We attempted to modify the mount to spread the load over two or more chain links.

Milestone 4: Initial testing of system to identify deficiencies.

This was conducted and is partially documented in Mr. Macpherson's thesis. Unfortunately it demonstrated more problems with the test rig than with the gambrel mechanism. The method of mounting to the chain was not sufficiently stable and was

Figure 8: The second prototype integrated with the test rig and showing the shoulder supports that prevent it from rotating excessively relative to the chain under the influence of tripping and resetting loads.

modified, as indicated above. The initial modification was to place mounting points on two links separated by one or two intervening links. This did not work well and placed additional loads on the chain. Ultimately the solution was to provide supports mounted to the upper cross-member of the gambrel as shown on Figure 8. These supports bear against the chain when the mechanism experiences a force opposing its motion, thereby preventing excessive rotation.

The triggering ramps need to be integrally mounted on the same frame as the conveyor chain. The chain needs more backing support in the regions where the mechanism interacts with the ramps.

The gambrel mechanism itself has proven to be unstable under load in the closed position. The load tends to cause the hooks to separate. This may be corrected by use of a stiffer spring, but at the cost of difficulty due to increased chain load when opening the mechanism. It has been pointed out that substantial loads are applied to the carcass, and hence the gambrels, in some parts of the process. Hide removal is a good example. Thus, this solution is probably not adequate. At the cost of complicating the mechanism, a second toggle, or other means might be added to lock the mechanism in the closed position.

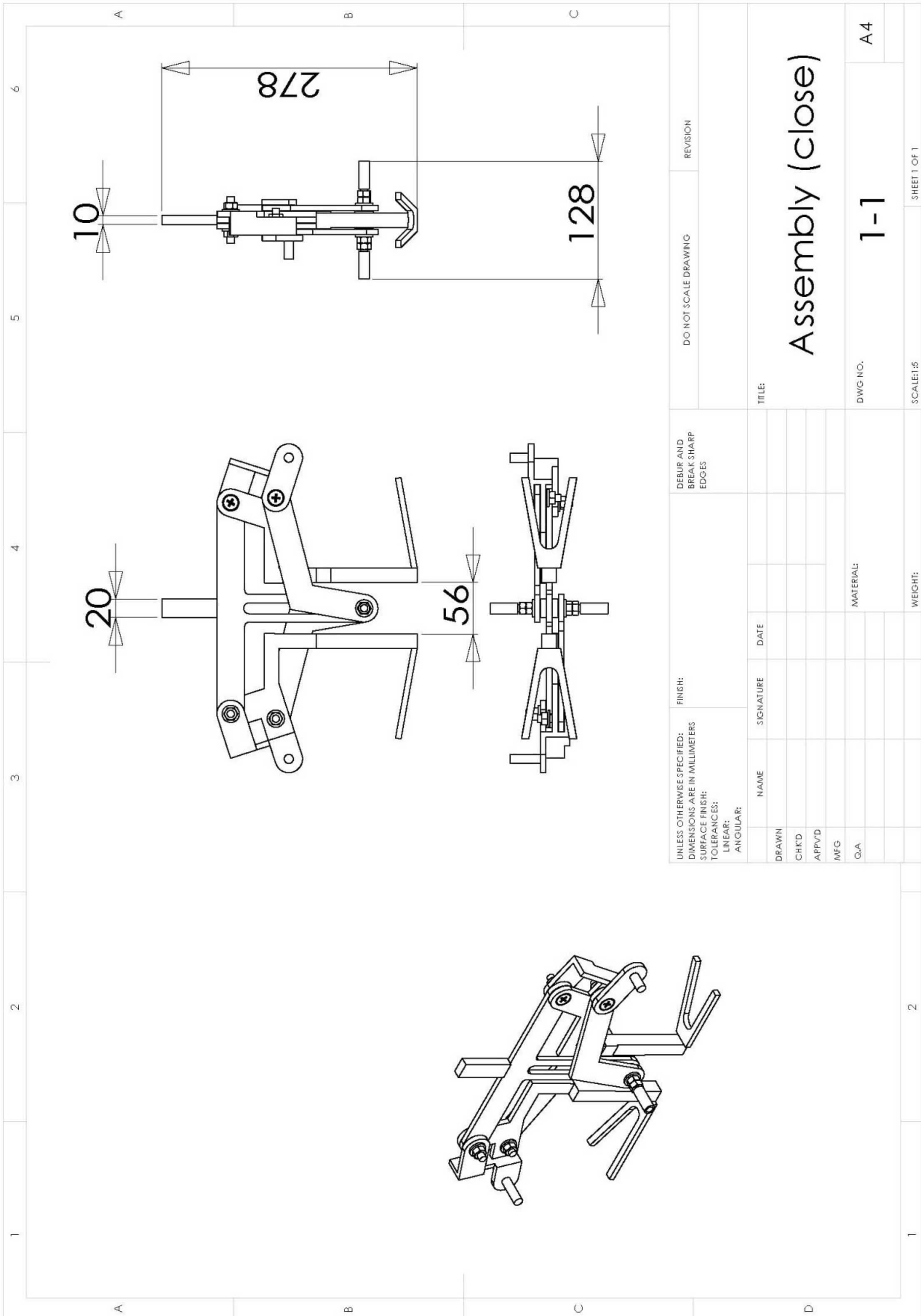


Figure 9: Assembly drawing of the final gambrel mechanism design shown in the closed position.

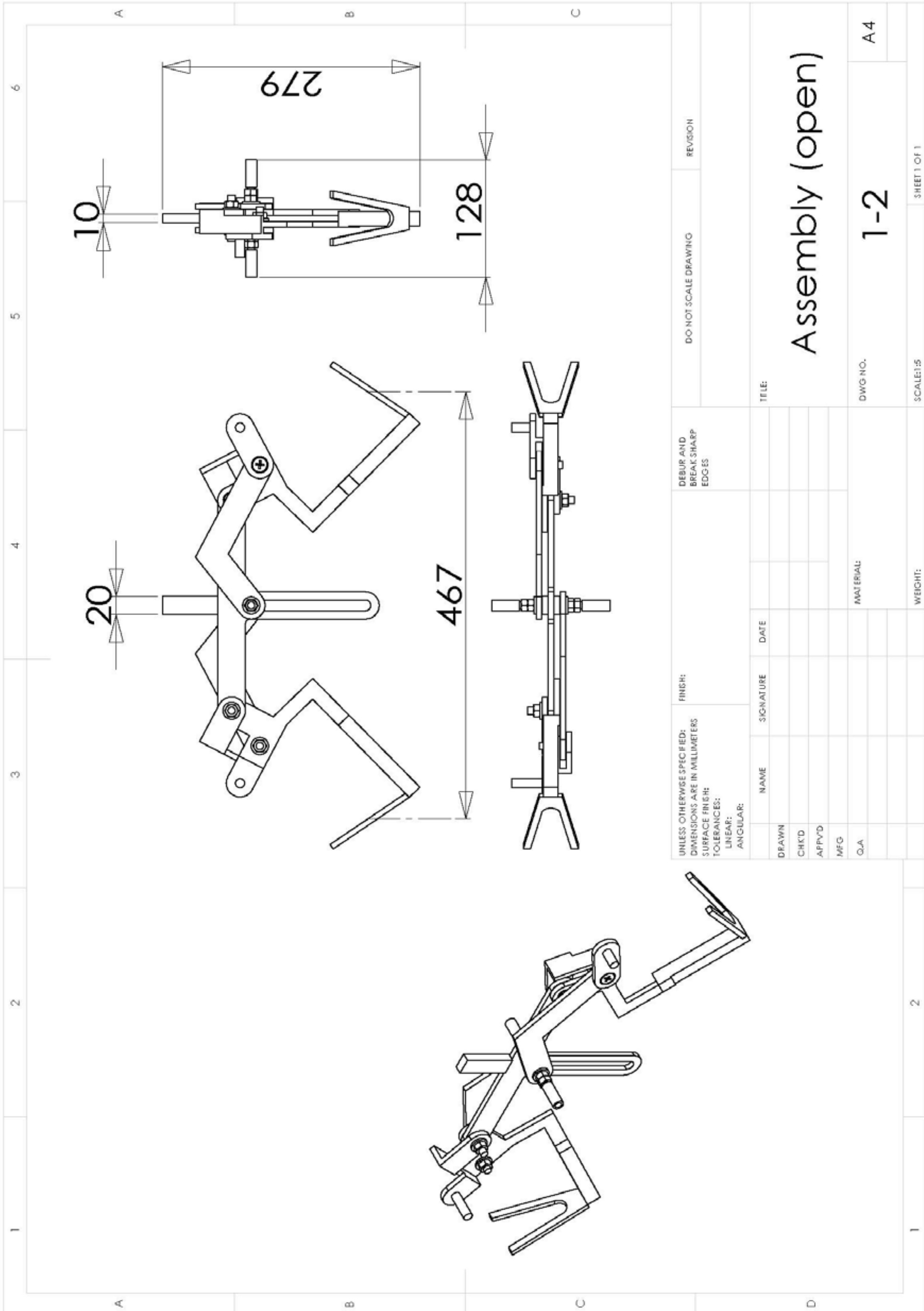


Figure 10: Assembly drawing of the final gambrel mechanism design shown in the open position.

The problems discussed here led to reconstruction of the conveyor rig, as partly detailed above. After testing on the modified rig, a second prototype was designed and constructed. That is the version shown on Figure 8.

The second prototype was designed to cure the problem of excessive force needed to open the mechanism, as exhibited by the first prototype, and to be stable under load. It was tested with loads of 5 kg on each hook. This is less than the weight of a typical sheep carcass, but was judged to be the maximum that could be handled by the much lighter chain used in the test rig. It did demonstrate closing of the mechanism under load, and did demonstrate the stability of the second prototype under load, in contrast with the first prototype. One important point is that, as long as it does not cause the hooks to separate, the presence of a load actually stabilizes the mechanism, and improves its behavior when tripped to close it.

Milestone 5: Identify and carry out necessary design modifications.

Several issues were identified during testing of the second prototype. A third design was completed to overcome most of these issues. One of the important ones is lack of clearance height above the hooks for placement of the hooves. The hinging of the hooks was also judged to be undesirable. The new design corrects both of these issues. A layout drawing of this design is shown as Figure 9. A complete set of manufacturing drawings is included on the accompanying CD.

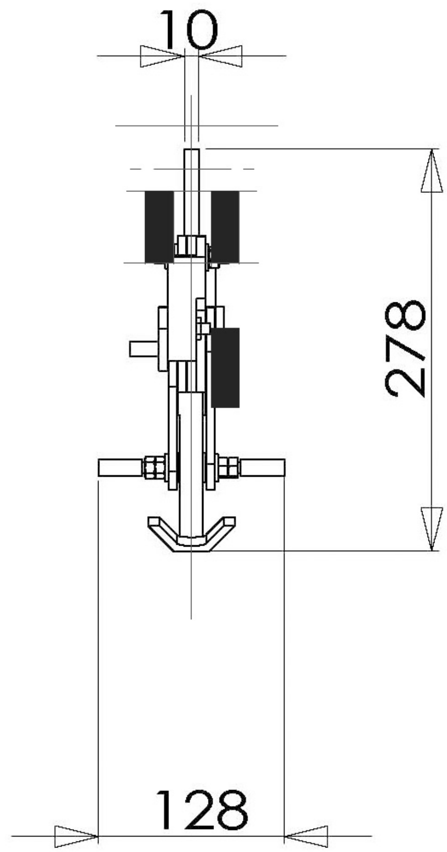


Figure 11: View of the final design mechanism in closed position from along line with nylon lateral supports for the shoulder puller indicated in black. The measurements are courtesy of Chris Riddle, CRF.

There is still a problem of interference between the mechanism and the nylon guides used in parts of the process in which lateral support of the gambrel hooks is needed (Figures 11, 12 and 13). On a line set up to use the automated gambrel mechanisms the necessary supports could easily be redesigned and placed so interference would not be a problem. However, for purposes of testing the mechanism in a plant it would be necessary to temporarily remove the lateral supports. It appears to be unlikely that a set of lateral supports could be designed that would be compatible with both the existing and automated mechanism, because of the difference in width.

As previously communicated, the CRF process includes repositioning of the hocks in the gambrel at the first transfer. The current design maintains gambrel height in the open and closed positions, which appears to be compatible with processes employed by other companies.

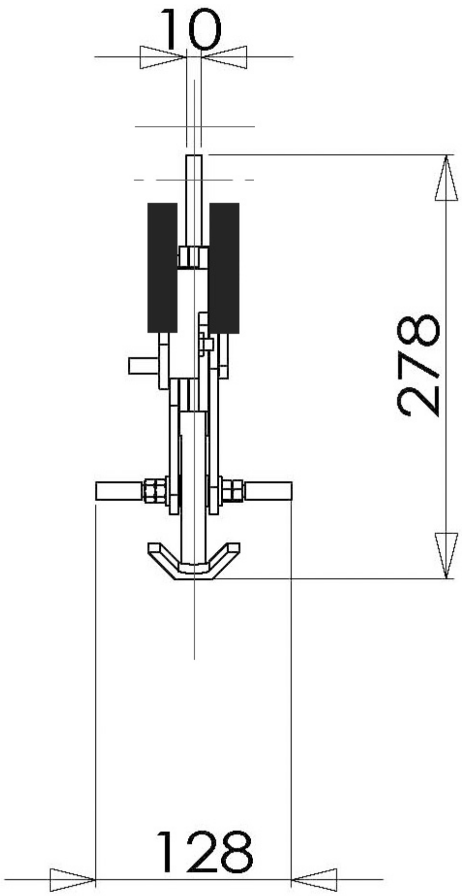


Figure 12: Front view of gambrel mechanism in closed position with nylon guide blocks for final puller shown in black. Measurements courtesy of Chris Riddle, CRF.

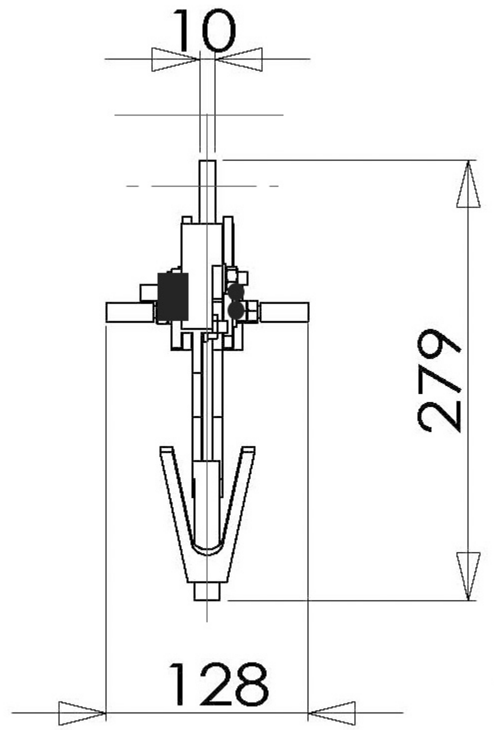


Figure 13: Front view of gambrel mechanism in open position with nylon and rail guides for the Y-cut shown in black. Measurements courtesy of Chris Riddle, CRF.

An additional necessary modification is redesign using process compatible materials. This is primarily replacement of the mild steel used in the prototypes with stainless steel, but also encompasses selection of self-lubricating bushing and spring materials that are compatible with food processing.

Milestone 6: Demonstration of completed system.

This work encompasses manufacture of a process compatible prototype and demonstration of its operation online in a processing plant. It will also be necessary to design support structures for the triggering stops that are compatible with the configuration of the process in the plant chosen for the demonstration.

As was mentioned above, there is a problem with the lateral support guides used in parts of the process to support the gambrels against forces generated by pulling the hide etc. For operation using the gambrel mechanism described here it would be necessary to design supports that are compatible with the two-position mechanism. That modification would be straightforward, but unfortunately it does not appear to be possible to design guides that would be compatible with both the existing gambrels and the new mechanism described here.

This demonstration will require negotiation of the logistics necessary to secure access to the subject slaughterhouse conveyor during an off shift in order to mount the mechanism and the stops, and temporarily remove guides with which it would interfere, and to test and demonstrate its operation. Given the lateral support guide problem, and the need to test during a down shift, it would probably be impractical to run carcasses supported on the two position mechanism through the entire process.

For these reasons, the work originally envisaged for Milestone 6 was not completed during the project period.