Final Report

AUSTRALIAN MEAT PROCESSOR CORPORATION

Beef Anti-Sway

Beef Anti-Sway Concept and Trial Study

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1.0 Executive Summary

There are many barriers to adoption of new technologies within the red meat industry, including changes of processes and risk associated with all new technologies. In addition to this, a major barrier is the return on investment (ROI) of a system. One way that the ROI can be improved for a system that recoups capital expenditure via yield gains, is through increasing the throughput of the system, allowing for the yield gain to multiply more rapidly. As a result, increasing the speed of beef side indexing is a possible way to increase adoption of technologies, by reducing an automated system's ROI, and footprint.

Throughout this project, multiple beef index control concepts and methodologies were developed, tested and analysed to understand the applicability of such methods to meat processing. As a result, a trial rig was designed and manufactured, to allow the testing of the concepts and assumptions made throughout the concept design.

Once installed on site, trialling was performed in a range of different configurations and methodologies. Several different configurations were found to be feasible to address different red meat use cases.

The results of this project indicate that the index times are significantly reduced when using a range of different advanced motion technologies, and that such technologies are applicable to beef side indexing. By the introduction of index control technologies for beef side indexing, throughput can be significantly increased and the ROI for automated systems can be further reduced for easier adoption. The use of such a system reduces risk for a range of different machinery that require and indexing approach.

The next step is to develop a use case for index control indexing of beef sides into an automated machine, using one of the methods of indexing presented. This will further cement the use of this technology in industry, and allow analysis on ROI differences due to the addition of this technology.

2.0 Introduction

There are many barriers to adoption of new technologies within the red meat industry, including changes of processes and risk associated with all new technologies. In addition to this, a major barrier is the return on investment (ROI) of a system. One way that the ROI can be improved for a system that recoups capital expenditure via yield gains, is through increasing the throughput of the system, allowing for the yield gain to multiply more rapidly. As a result, the speed at which a carcase can be indexed into a system is integral to the ROI of a system. This project will focus on the concept of enable high-speed movement of a beef carcase while limiting excessive unwanted movement, resulting in an enabler for higher-speed automated processing. Within this field of study, there are also considerations given to:

- How to stabilise moving carcases
- How to reduce carcase rotation, and the added effects on required index times
- How to develop a carcase indexing system for possible use in any machine requiring carcase indexing on a chain

At the conclusion of this project, the applicability of advanced motion control technologies will be determined to the meat industry, in the form of beef side indexing.

3.0 Project Objectives

The objectives within this project are to:

1) Determine the applicability of index control technologies to red meat carcase indexing
2) Determine the feasibility of using such technologies to enable high speed indexing of beef sides for the possibility of indexing solutions for automated systems in meat processing.

There are a multitude of benefits produced within this project that are identified within AMPC's 2020-2025 Strategic plan, including:

1) Removing staff from dangerous operations, via hands-off processing.
2) Increasing safety and wellbeing, by reducing the high-risk nature or certain processing operations.
3) Attraction of people to the industry via demonstrating a wide range of technological operations.
4) Retention of people within the industry by improving working conditions.
5) Developing tasks that require higher skills and intellect.
6) Increasing carcase primal profitability through optimisation
7) Enabler for acquiring product and processing formation in order to leverage data insights.

3.1 Project Methodology

The project methodology of the Beef Index control Concept and Trial Study was:

1) Develop a concept to enable high-speed movement of beef carcases while controlling swing.
2) Develop a trial setup for the concept.
3) Perform initial factory trials using an appropriate analogue for a beef carcase.
4) Install trial assembly at a processor site and perform trials with actual beef sides.
5) Analyse results for index speed and technology feasibility.

4.0 Methodology

4.1 Concept Design

The first stage was the concept design - coming up with a general design of a system that could control the swings and oscillations of a beef carcase if it were to be accelerated and decelerated quickly. Such a system could have a multitude of actuated components to halt the motion of a beef carcase once moving quickly. A number of concepts were explored using a combination of motion control and mechanical means to control the motion of the carcase.

4.2 Mechanical Design

Throughout the design conceptualisation phase, a list of design constraints as well as testing outcomes was developed and taken into account. These factors drove the final concept to ensure our design would meet the targeted throughput and answer any unknown variables.

The primary design constraints taken into account were:

- Trial Rig Dimensions
  - Required to accommodate various carcase sizes and able to fit inside test site chiller rooms.
- Modularity
  - Easy to disassemble and adjust locations of various actuators/conveyors for ease of optimisation.
- Speed
  - Actuators had to meet throughput demand
- Material selection
  - Contact surfaces with the carcase must be food safe and able to be cleaned. Consider washdown environment during component selection.
- Safety
  - Operator safety is an important design consideration which needs to be accounted for. There will be heavy equipment operating at high speeds, hence, we need to ensure that the design accounts for the safety staff operating in close vicinity to the trial assembly.

Considering the constraints and test variables, a trial rig was designed using 3D CAD.

4.3 Electrical Design

The electrical design was also carried out, in parallel and in conjunction with the mechanical design. The primary concern was the search for the supplier with the most suitable equipment. A range of different vendors were approached, and the application was discussed in a range of different technical meetings. Once the suppliers were determined, the electrical system was developed and continued to the point where the BOM was completed, and the electrical drawings were fully generated.

On the completion of the mechanical and electrical design, the required components were purchased, and manufacturing began.

4.4 Trial Assembly Manufacturing

The first step that had to occur, was the manufacturing of the trial assembly. This comprised of a range of modules that make up the whole index control trial rig.

4.5 Programming

Prior to the manufacture of the trial assembly, the programming was performed and simulations were built, so most of the software was able to be simulated and debugged before receiving any of the hardware.

The advanced motion algorithms were programmed next, to build on the fit for purpose trialling that was previously performed.

The safety program also had to be built, in accordance with the Safety Risk assessment performed, and the required safety functions that were extracted from the analysis. Two estops are to be used as safety devices, and Safe Torque Off functionality inherent within all the drives are to be utilised to safely isolate the output power of each drive. As a result, a very simple safety program was built to allow Estop functionality to control the STO of each drive.

Next, the program structure had to be set up to allow for the individual software modules to work together to allow for the system to be controlled as specified. As a result, a primary program was set up in order to control the state of each module.

A GUI was also built-in order to allow for easy control and changing of parameters on site, to facilitate quicker trialling and commissioning. This GUI allows for:

1) Changing of all control parameters
2) Control of the system state machine
3) Actuation of mechanical components
4) A graph page to show results.

Before performing the factory trials, a simulation was performed to ensure all written software modules worked together and were integrated together correctly.

4.6 Site Trial Plan and Methodology

Since time on site to carry out the trials was limited, it was critical to develop a test plan and methodology in order to ensure milestone deliverables were met, and the various tests which needed to be conducted were prioritised. The beef anti-sway project involved developing a concept to enable high-speed movement of a beef carcase while limiting excessive movement. The goal for this trial was to find a configuration that best stabilises the carcase.

Using this trial plan as a guide allowed timely delivery of the trial objectives. Once the test configurations were determined, a test methodology for each phase of the trial was developed.

Below is an outline of our test objective during each stage of the trial: -

1. **Installation and Commissioning**

The first priority was to assemble the trial rig on-site and ensure all components could function as intended without any obstructions on site.

2. **Index control Trials**

The intention with these trials was to assess feasibility of using index control profiles to minimise carcase swing. The amount of residual movement after the side had completed its index would be measured.

3. **Integrate mechanical components**

Actuate the mechanical stops at various angles and speeds to assess whether our target speed is achievable. The assessment included its ability to stop residual inertia in carcase after the motion control velocity profiles had ended.

4. **System Speed Trials**

Vary numerous parameters to optimise for indexing speed.

4.7 Site Installation

First, the system had to be installed on the client's site while ensuring their production schedules during the day were not disrupted. As a result, the system was brought into the facility during night shifts and assembled for the subsequent trials.

Since there were limited resources in the chiller room to assist in assembly of the tall frames, a scissor lift along with multiple chain blocks were utilised to assist in lifting the various frame sections. Extra time and care needed to be put into this stage of the project as to ensure there was enough space in the chiller room to allow manoeuvring of the frames into their various test configurations.

4.8 Site Trial #1

The first trial was to perform our initial index control trialling, by using our index profile to move the carcase hook, and our stabilisation system to arrest any energy that was not removed through the velocity profile. This testing was performed using a range of sides to understand the total index time, and the effect of initial carcase swing on the system. Initially, the system was commissioned and the stabilisation actuation speed and acceleration values were found through trialling a range of different values.

4.8.1 Index control Parameters

Initially, trials were performed to measure the speed of the index, and the sway of the carcase post index. It was expected for the carcase to attain some sway, due to the imperfections of the system that makes a beef side not a perfect mathematical model.

Trials were performed for a range of carcases to determine the index time, and also the amount of sway we received when not using mechanical stabilisation at the end of the index. The index time was compared and analysed for a range of different carcases.

4.8.2 Induced Swing Index control Testing

In addition to testing with various input parameters, the sides were tested by inducing some sway into the carcase at the beginning of the cycle, to determine the effect of initial swing on the carcase. It was hypothesised that this would cause an increased swing and, therefore index time. As a result, index times were measured for an initially swinging carcase.

4.9 Site Trial #2

The next configuration to try the advanced motion algorithms with the carcase oriented differently and a different assembly of mechanical stabilisers. Whilst analysing the mechanics of the carcase being processed in this orientation, it was evident why there is increased stability and consistency in our data.

4.10 Site Trial #3

The next configuration to trial was to run the same test as trial #2, with an additional stabilising mechanism. The values obtained here seem to be more consistent than previous tests, with smaller changes between the different scenarios. From the improvement in standard deviation, it could be seen that using the additional stabilising surface gives us more control over a larger sample set of carcases.

4.11 Site Trial #4

The next configuration of index control to trial was to remove the motion velocity profile from the movement of our carcase, and use a different actuation device to perform the index. This arrangement simplified the mechanical arrangement overall of the system.

4.12 Site Trial #5

After the analysis of previous index control results, to perform indexes on the carcase in its original orientation from trial #1, additional stabilisers were fashioned. The tests were then repeated to understand the impact these stabilisers had to overall indexing time. The results showed faster index times and more consistent results.

4.12.1 Unique Carcase Profile Testing

The Index control trials were performed again, but with carcases out of the ordinary. This included extremely small carcases, and sides that have had parts removed for a range of reasons. The results were extremely similar to the results initially obtained, demonstrating that the index control system can handle a large range of different carcase profiles, including particularly small carcases, and sides that have had parts cut out from them previously.

5.0 Discussion

Throughout this trial, a range of different index methods were trialled, to allow for different possibilities for different processes. Based on the results obtained, the best index method was identified. Unfortunately, there are only a small number of meat industry processes which make this ideal arrangement feasible. The best indexing method allowing for a wider range of use-cases was also identified, including a development pathway for what it may look like for a commercial system and how the concept could be further developed.

Based on the results achieved, it is evident that this method of beef side indexing can be used for a range of possible automated solutions within meat processing plants, due to the quicker index time relative to older systems, where the index movement had to be slow to ensure carcase stability. This method would certainly decrease the ROI required, enabling easier adoption of technologies within industry.

6.0 Conclusions / Recommendations

Throughout this project, multiple concepts for the index control and anti-rotation of indexing beef sides were developed, tested and the results were analysed. The ability to perform indexes quickly allows for stationary processes to increase accuracy of robotic processes, while still ensuring throughput. The results found through these trials was that there are methods to index carcases in varying orientations by making use of different stabilising mechanisms combined with advanced motion control velocity profiles.

As a result of this project, the hypothesis of the applicability of advanced motion control technology to assist in faster indexing systems for beef sides has been confirmed. This confirmation is evident through the measured index times.

The results of this project indicate that the index times are significantly reduced when using a range of different index control technologies, and that advanced motion control technologies are applicable to beef side indexing. By the introduction of index control technologies for beef side indexing, throughput can be significantly increased and the ROI for automated systems can be further reduced for easier adoption and a reduction of risk for a range of different machinery that require and indexing approach.

The next step is to develop a use case for index control indexing of beef sides into an automated machine, using one of the methods of indexing presented to further cement the use of this technology in industry, and allow analysis on ROI differences due to the addition of this technology.