Final Report

AUSTRALIAN MEAT PROCESSOR CORPORATION

Waterless Lamb Frenching – Public Release Version

Waterless Lamb Frenching Concept Trials – Curious Creations

Project Code	Prepared by	Date Submitted
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Contents

1.0 Executive Summary

The scope of this research project was to further develop and test the automated waterless lamb frenching prototype that was conceptualised by Curious Creations Ltd. An automated lamb frenching machine is highly desirable by the meat processing industry due to sustainability and safety issues with the two existing solutions of water frenching, and manually frenching.

A prototype was successfully designed and developed that incorporated a continuous automated feed mechanism with a method of removing the intercostal meat from the rib bones of the lamb racks. The prototype demonstrated that this process has potential to be commercially viable with a maximum speed of 36s required to process a lamb rack, and a small footprint occupied by a single machine. The finish achieved on successful tests was of a similar quality to that achieved by water frenching, with none of the sustainability or reduction in shelf life issues encountered with the use of water.

The prototype is currently unable to adequately deal with the variation seen on some of the lamb racks tested. Recommendations have been made on how to improve the prototype, which are expected to resolve the issues that have been encountered in this project.

2.0 Introduction

The purpose of this research project was to develop an automated waterless frenching solution as a safe and sustainable alternative to frenching with water or knives. In Australia, most processing facilities rely on operational staff with knives to undertake this activity. There are instances in Australian plants using the McLaren Stainless water frenching solution. Although this solution works well it is not suitable for all Australian locations due to the water usage, water source, and resulting additional trade waste load with the product (intercostals) and water being discharged to drain. Each 8-rib rack requires at least 21 knife actions (and up to 23), this activity results in up to 210,000 knife actions per operational staff member within a plant operating at 10 carcases per minute. This task has both a WHS repetitive strain and knife laceration safety concern.

Prior to the beginning of this research project, Curious Creations had produced a basic proof of concept device to demonstrate the effectiveness of their idea, and a basic CAD model of the prototype they were looking to build. The scope of this research project was therefore to complete the detailed CAD design of the prototype, build the prototype, and test the prototype in order to determine whether the concept would be commercially viable. The design of the prototype to the relevant food hygiene and safety standards were out of scope for this project, and these would be addressed at a subsequent prototype, should the concept prove to be successful.

3.0 Project Objectives

The following Project Objectives are detailed in the Research Agreement between Curious Creation Limited and AMPC:

1. Further develop and test the automated frenching method conceptualized and proven by Curious Creations Limited;
2. Incorporate the automated frenching method with an automated feed mechanism;

3. Increase the speed of the process to a commercially viable level;
4. Further test the reliability and repeatability of the process.

4.0 Methodology

The project was broadly conducted in accordance with the milestone schedule listed in the research agreement. The Systems Engineering V-Model displayed in Figure 1 was followed to produce the detailed design of the prototype from high level system requirements, and test the individual components and subsystems of the prototype against sub-system design requirements prior to testing the complete system.

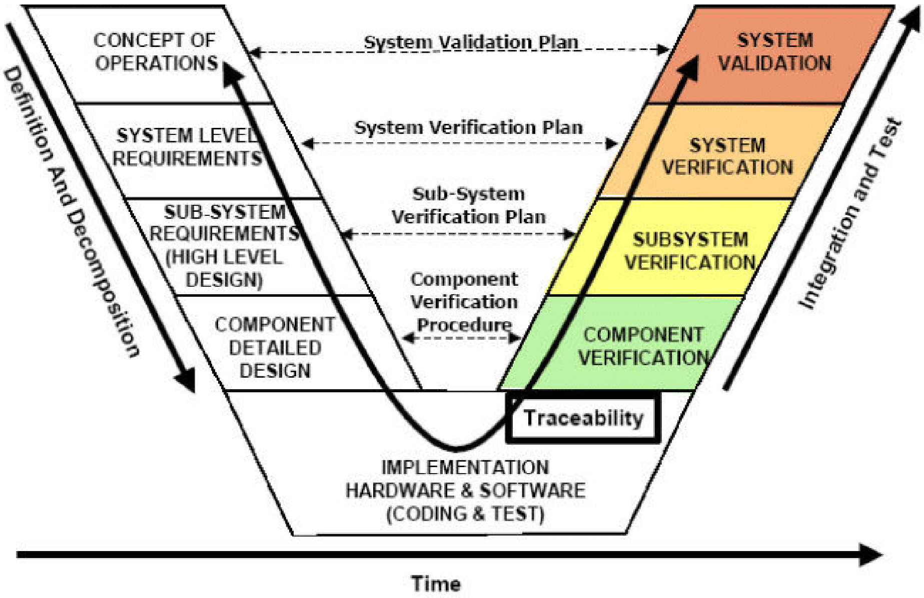

Figure 1: V Model Systems Engineering design process

4.1 Detailed CAD Design

At the commencement of the project, Curious Creations had already produced a proof of concept device, and a basic CAD model of the proposed prototype. The first stage of the project was therefore to complete a detailed CAD design to enable manufacture of the proposed prototype. The CAD design was completed in the following manner:

- Detailed CAD model of the sub-systems;
- Selection of of-the-shelf components to support the sub-systems;
- Detailed CAD model of the full assembly, incorporating all of the sub-systems;
- Validation of some models through 3D printing;
- Confirmation through the METCO Design Engineer that the machined components were appropriately designed for manufacture.

4.2 Ordering Required Components and Assembly of the Prototype

Upon completion of the detailed CAD design, a parts list was produced and all of the required components were ordered. Assembly of the prototype was completed in phases as components arrived. In a similar process to the Detailed CAD Design, sub-systems were assembled individually before assembly of the complete prototype. This allowed for initial testing of sub-systems to be completed while waiting for components for other sub-systems to be delivered.

4.3 Produce Microprocessor Code

The Arduino Mega board was selected as the microprocessor for this project due to its ease of use, relatively low cost, and ability to easily compute algorithms and interpret sensor readings. It is also compatible with the analogue position sensors, pneumatic control valve relays, and stepper motor drivers used in this project.

Arduino boards are programmed using Arduino software which utilises the Arduino programming language. The Arduino programming language utilises a variant of the C++ programming language and is commonly used in prototype projects. Because of this, there is a large amount of information and examples available on the internet.

To produce the Arduino code for the lamb rack frenching prototype, first Pseudocode was produced. Pseudocode is a simplified version of the code where lines are written in plain English, rather than the precision required in formal coding language. This allows a plan of the high level code structure to be produced that focuses of the program logic without needing to focus on precise syntax. Each detailed section of the code was then produced for the individual systems of the prototype.

The code was tested in sub-systems, as hardware components of the prototype were delivered and assembled. Once all of the sub-systems were completed and working, and the prototype was assembled; testing of the complete system could commence. This involved utilising a 3D printed lamb rack mock-up for the purpose of testing the ability of the prototype to accurately sense and position the lamb rack within the frenching mechanism. Compressed air was then provided to the machine to ensure that the mechanisms moved as expected. The lamb rack mock-up was fed through the machine repeatedly to simulate a processing environment and ensure that the program produced was capable of sensing, storing and wiping data used to sense and position the lamb racks.

4.4 Prototype Testing

The following testing procedure was completed in order to best meet the project objectives listed in the research agreement. Broadly this involved testing the two major sub-systems individually to resolve integration issues encountered with each sub-system, and confirm that the sub-systems could meet their individual design requirements, before testing the complete prototype.

Once the function of the sub-systems was confirmed, testing of the full prototype could commence. The prototype was initially programmed to run slowly to allow time to react to any conditions that may cause damage to the machine. The prototype was also programmed to pause before carrying out each operation, and a safety button needed to be pressed by the operator to confirm it was safe to continue at each step.

18 lamb racks were then fed through the machine over three testing sessions, and adjustments were made between testing sessions to improve the performance and resolve problems encountered. During this period multiple cycles of testing and development were carried out to further refine and develop the prototype. Many changes were made to the prototype utilising 3D printed components to enable rapid prototyping. The speeds of the actuation systems within the prototype were then increased in order to determine the maximum viable speed of the prototype.

5.0 Project Outcomes

The project outcomes have been defined against the project objectives listed in Section 3.

5.1 – Objective 1: Further develop and test the automated frenching method

The prototype developed in this project has significant developments over the first proof of concept mechanism developed by Curious Creations.

Initially the automated frenching sub-system was tested in isolation without using the automated feed sub-system. This involved manually aligning the lamb rack to simulate an ideal performing automated feed sub-system.

After the preferred configuration was identified, the automated frenching sub-system was further trialled with favourable results. Figure 2 shows some of the results.

Figure 2: Results achieved during the automated frenching sub-system testing

5.2 – Objective 2: Incorporate the automated frenching method with an automated feed mechanism

An Automated Feed sub-system was successfully developed and incorporated in this prototype. This sub-system consisted of two pairs of opposing conveyor belts that enabled a continuous feeding process for the prototype.

The conveyor belts were made from specially designed, 3D printed components. These were produced as no existing commercial options could be identified that met the requirements of this project.

A sensor was incorporated into the automated feed subsystem. This was read and interpreted by the Arduino board to determine the location of the bones in the lamb rack.

Once the Automated Feed sub-system was developed as far as practical within the scope of this project, the complete system was ready to be tested. Figures 3 and 4 display the range of results that were achieved, with Figure 3 displaying an ideal test with relatively straight bones, and Figure 4 showing a failed test where bones have been broken due to inadequate operation of the automated feed sub-system. Note that Figure 4 was taken from an earlier testing session actuation pressures had been optimised. This is the reason for some intercostal remaining on the straight bones. In comparison, Figure 3 was taken from the final testing session once the actuation pressures had been optimised.

Figure 3: Ideal test result

Figure 4: Failed test result with broken bones

5.3 – Objective 3: Increase the speed of the process to a commercially viable level

In order to increase the speed of the process, the following changes were made to the prototype:

- Air flow restrictors opened to allow the maximum air flow that could be safely provided by the valve body (with maximum actuator inertia in mind);
- Delay times in microprocessor code were reduced to a point just prior to where the processes overlapped;
- Conveyor speeds were increased to the maximum possible under the current configuration.

As the conveyor design allows for a continuous production flow, the maximum speed of the system should be considered as the time taken for the slowest process to be completed. In this prototype, the automated frenching sub-system is definitely the ‘bottle neck’ with the lamb racks moving relatively quickly through the sensor.

At the highest successfully tested speed of the prototype, it was found that it took 36 seconds for the 8 bones of the lamb rack to move through the automated frenching sub-system.

5.4 – Objective 4: Further test the reliability and repeatability of the process.

Reliability

The prototype proved to be reliable once the initial issues were resolved. Further high cycle testing is required to determine the wear life of key components.

Repeatability

Some issues were encountered with the variation of the lamb racks trialled. Further changes are required to be made to the prototype to address these issues.

6.0 Discussion

6.1 – What Factors External to the Design of the Prototype Impacted the Results?

During testing it was noticed that fresh samples were a lot easier to process than older samples. All of the racks were procured from a local butcher in the chined, cap on state. Prior to frenching, the cap was removed by tearing it from the rack. Fresh samples tore off much easier as the fat layer had not fully set and hardened. This also carried over to the frenching process where it was noticed that the intercostal meat was easier to remove and came off cleaner on fresh samples. On the later testing sessions, arrangements were made with the butcher to procure samples and carry out testing on days that they were due to receive lambs in order to improve the freshness.

6.2 - Is the Speed of the Prototype Commercially Viable?

Previous research funded and published by AMPC (Wong, 2016) identified that one processing facility that was manually frenching lamb racks was processing 9 racks per minute, or one rack every 6.7s. In order to achieve this they had four people frenching the lamb racks (which had the cap already removed) who were occupying a bench space of 2.5m x 1.5m, or 3.75m^2.

The maximum speed achieved by the prototype was one lamb rack every 36s. In order to achieve the throughput of the facility in the described example of one lamb rack every 6.7s, this facility would require a minimum of 6 automated frenching machines. Based on the size of the prototype, this would occupy a floor space of approximately 2.4m x 0.7m, or 1.68m^2 which is only 45% of the floor space occupied by four people manually frenching.

Based on this example, a 36s processing time would be commercially viable for facilities that are currently manually frenching. It is likely that the processing time could be further reduced however this would only serve to increase the wear and reduce the operating life of the high wear components. Effort would be better spent to further reduce the packaging size of future prototypes and design the system to be modular so that multiple units can be stacked together easily.

6.3 - Is the Cost of the Prototype Commercially Viable?

Utilising the example described in Section 6.2, it is likely that this facility could reduce the number of frenching operators from four people to one person. This would allow one person 6.7s to load each rack into the automated frenching machines. Assuming a labour cost of $80,000 per person per annum, the 6 automated machines would need to be procured and installed for less than $240,000 (approximately three employees for one year) to achieve an ROI of 12 months. Based on the cost of producing the prototype, and the economy of scale that could be achieved by producing multiple machines, it is highly likely that the prototype is commercially viable.

At this stage it is difficult to predict the operating cost of the prototype, as the operating life of the high wear components has not been confirmed.

7.0 Conclusions / Recommendations

The project objectives have successfully been achieved and significant progress has been made in the development of an automated waterless frenching machine. The process has potential to achieve the required finish and throughput to be a commercially viable option. As described in this report, there are still challenges to be resolved to produce a repeatable process and potential solutions have already been identified to achieve this.

It is therefore recommended that:

- Further development and testing is carried out with the current prototype to address the challenges discussed in this report.
- Upon resolution of the discussed challenges:
    - Investigate IP protection options.
    - Design and produce a second prototype that incorporates the required machine guarding and food hygiene standards to be trialled in a processing facility.

8.0 Bibliography

Wong, P., 2016. *French Dressed Lamb Rack Preparation Robot Cell (Stage 1),* Sydney: Australian Meat Processor Corporation.