Final Report

AMPC
AUSTRALIAN MEAT PROCESSOR CORPORATION

# Robotic X-Ray Cable Trials

## Robotic X-Ray Cable Dynamic Stress Testing Trials


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# 1.0 Executive Summary

X-Ray driven technological solutions for beef and lamb automation are currently designed with fixed x-ray solutions. In addition to this, similar existing x-ray technologies for the detection of metal, fat/lean trimming and QA are also fixed x-ray in nature. As a result, there is a gap in knowledge around how dynamic and moving x-ray installations can be done while ensuring an adequate lifetime for the x-ray cables being used, to ensure that the ongoing maintenance costs of moving x-ray installations do not cause barriers to adoption.

This study involved performing stress testing of a high-voltage x-ray cable using a robot moving through expected paths, at required speeds for a high-demand application. The robot was programmed to carry out multiple path profiles in order to stress the cable through its expected real world use case. The cable was then continuously stressed multiple path cycles.

After performing of the trials, the cable was assessed for damage/failure to confirm the robustness of the concept. To carry out this assessment, the cable was sent back to the manufacturer to be broken down and assessed for any damage. The assessment found that there was no notable damage on all layers of the X-Ray cable assembly.

The main goal of the trials was to run the X-Ray cable through a stress test in order to evaluate whether there would be any significant maintenance implications during the course of its service life in the field. Confirming we have a robust and fit-for-purpose cable would mean a reduction in maintenance costs for the customer in the future, thus adding additional value for them.

Since the testing showed no major lifetime implications for the cable when exposed to high stress movements, it was decided that no further testing or evaluations would be required in this space. We will, however, need to pay close attention to how our simulated path may vary to the final real-world application.

# 2.0 Introduction

The aim of the project was to successfully perform factory trials using our simulated cable stress movement profile in order to assess the feasibility and design requirements for a robust x-ray scanning system. The project was completed successfully, with the completion of the robot trial setup, the programming of continuous robot movements and finally the detailed breakdown and assessment of the cable.

# 3.0 Project Objectives

Current X-Ray driven technological solutions for beef and lamb automation are designed with fixed x-ray solutions. In addition to this, similar existing x-ray technologies for the detection of metal, fat/lean trimming and QA are also fixed x-ray in nature. As a result, there is a gap in knowledge around how dynamic and moving x-ray installations can be done while ensuring an adequate lifetime for the x-ray cables being used, to ensure that the ongoing maintenance costs of moving x-ray installations do not cause barriers to adoption.

This study will involve performing stress testing of a high-voltage x-ray cable using a robot moving through expected paths, at required speeds for a high-demand application. After performing of the trials, the cable will be assessed for damage/failure to confirm how robust our concept is. The main goal of this project will be to assess the feasibility and design requirements for reliable x-ray scanning on a robot.

## Project Methodology

The methodology of this project involves:

1) Obtain a robot for the project, procure a high-voltage x-ray cable, to run along the robot and fasten to the roll face.
2) Program several robot moves simulating scan paths at the required speeds for red meat industry applications.
3) Perform the movements continuously on the robot for an extended period
4) Remove the cable and have it assessed for any damage
5) Analyse trial results to assess feasibility of robotic x-ray scanning, which moves can/can't be made, and what design considerations apply.

# 4.0 Methodology

## 4.1 Harness Design

To assist in the reduction of surface contact between the robot and the conduits carrying our cable, we opted for a cable tensioning mechanism typically used to isolate conduits from contact against the robot and also reduce the likelihood of the conduits catching onto surfaces whilst carrying out a motion. See below typical application of a conduit tensioning mechanism (outlined by Roboway): -

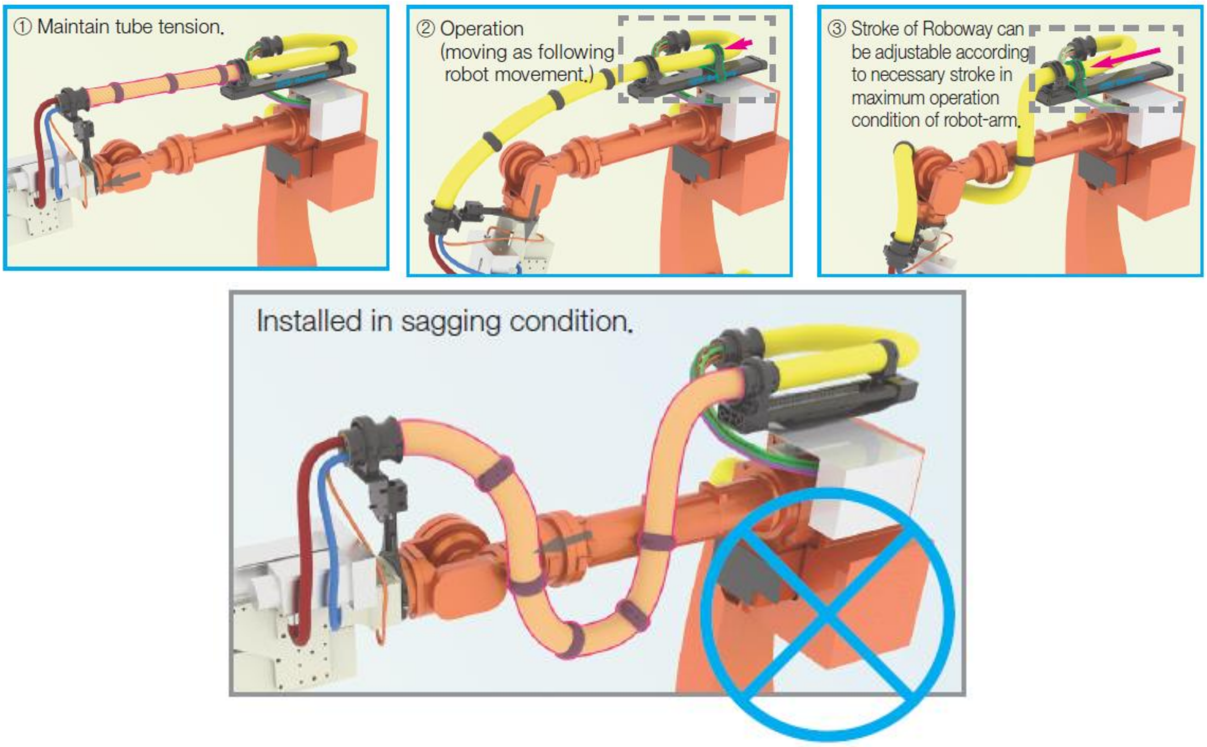


*Figure 1: Benefits of Tensioning Mechanisms*

As seen in the image above, the excess sagging condition is not ideal as it can lead to the conduit bumping against the robot arm multiple times which causes a catch-point risk for the cable/conduit on the robot arm, as well as accelerating wear of the cable/conduit and/or the robot coating.

## 4.2 Robot Movement Simulation

Following the development of a simulation of a possible X-ray solution for red meat, this simulation was translated into our robot programming software to allow for the robot program to be developed. This was setup to allow for a robot to perform various x-ray scans of a carcase (using an X-Ray source on the robot roll face) on both left-, and right-hand carcases. The program was set up to allow for all required moves and a simulation was run to ensure that there was no possibility of collisions or singularities within the robot path.

This program was then ready to be uploaded onto the robot whilst running at a slow speed initially and then ramped up as each speed increment is confirmed.

## 4.3 Part Procurement

Once all the components were designed, everything had to be procured for the trials. These included:

1) The X-Ray Cable
2) The Robot
3) The Robot Base
4) The Pneumatic cylinder for the cable harness
5) The Cable Harness

Once procured, all components were sent to site for installation and setup.

## 4.4 Design Requirements

The main components which needed to be designed for this X-ray cable stress analysis trial included: -

- **Robot Base** – To raise the robot and position it at a 10-degree angle to the ground to simulate our real-world reach profiles.
- **Robot End Effector** – This is what our X-Ray cable would connect to. One end of the cable will be fixed to this end effector whilst the remaining length is able to move dynamically through the harness.
- **Cable Harness & Tensioning Mechanism** – The robot harness and tensioning mechanism needed to be adapted to the robot arm mount points. It will also need to accommodate the multiple conduits and Xray cables going through the conduit clamps to leave enough slack in the system to move freely.

## 4.5 Trial Assembly Manufacturing

Once our various design features for the trial were conceptualisd. We were able to move on to manufacturing each of our critical components in preparation for the trials.

## 4.6 Factory Trials

Once all components arrived at site, the robot had to be set up and the cable runs had to be organised to trial out the robustness of the X-ray cable in a moving installation. Initially the robot was installed on the robot base, and the robot base was fixed to the floor, and then the cable harness was installed, and the gripper was attached to the roll face.

## 4.7 Cable Stress Testing

After installation was complete, the programmed robot movement simulation was ready for testing. For the initial cycle, the robot simulation was initiated at a low speed. To confirm there were not collision points and also to help eliminate any extreme stress points on the conduit by either modifying the code or increasing the length of the conduit between the harness and the end effector.

Once the cycle functionality was verified, we were able to run the simulation at full speed in order to stress test and determine whether our selected cable can handle the application. The cable was then put through multiple cycles.

Due to the conduit and X-Ray cable's lack of collision with the robot, the tensioning mechanism was not required to ensure the conduits did not rub and collide with the robot arm sections. Once completed, the Xray cable was detached from the end effector and inspected for any visual signs of damage on the exterior. Below are some images of the cable once removed: -

*Figure 2: Cable Condition - Post Cycle Testing*

Upon visual inspection by the operator, there were no obvious signs of damage along the length of the cable. The sheath was still intact and in good condition. To be certain that there was no damage to the internal structure of the cable, it was sent back to the manufacturer for a detailed visual inspection, electrical and mechanical integrity testing.

## 4.8 Cable Assessment

After factory testing was complete, the cable was sent to the manufacturer to complete an electrical integrity and visual inspection. This primary testing would verify the electrical integrity of the cable and give us an indication as to whether any damage or degradation had occurred during our robot simulation testing. The x-ray cable was connected to an x-ray tube and powered at 160kV. The test report from the manufacturer indicated no defects or visual faults were found. The cable also passed the electrical integrity testing which involved a full seasoning and burn in with the cable.

Further destructive testing was then carried out on the cable to determine whether any internal damage was sustained during the trials. This was a thorough destructive evaluation of the cable to inspect its internals for any signs of fatigue or damage.

# 5.0 Conclusions / Recommendations

During this trial, we were able to run the X-ray cable through a range of motions for multiple cycles. During the trials, we were able to see how the cables effective bend radius would work to accommodate the various simulated robot movements during a typical cycle on site. With enough slack on the conduits, we saw that there was enough space for the cable to manoeuvre freely without rubbing or catching on any part of the robot. This eliminated the need for us to use the harness as a cable tensioner which would only add additional stress to the system.

Upon completing the detailed evaluation of our X-Ray cable, we saw that there was no damage apart from some minor scuffing which was likely due to handling during transportation of the cable since it was not noticed on our visual inspection both at the trial facility and during our inspection at the manufacturers site. This shows that the cable can handle being exposed to the various bends during our cycle for an extended period of time, however, a point to note is that in a real-world application we would be exposed to significantly higher number of cycles as the cell is expected to operate for years.

Since our main objective of assessing the feasibility and design requirements for reliably x-ray scanning on a robot were achieved, there is no further testing planned. The trials showed us there would be no major lifetime implications for the cable when exposed to high stress movements. We will need to pay close attention to how our simulated path may vary to the final real-world application for any major changes to the scope of movement.

# 6.0 Bibliography

- Cpsystem.co.kr. 2021. *Roboway - Cable Tensioner*. [online] Available at: <http://www.cpsystem.co.kr/2017_re/sub02_01_07_e.html> [Accessed 12 October 2021].