High-Speed Sensing and Detection System for Automatic Removal of Packages with Seal Quality Issues from a Food Packaging Line

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ABSTRACT

Contamination of packaged foods due to micro-organisms entering through air leaks can cause serious public health issues and cost companies large amounts of money due to product recalls, consumer impact and subsequent loss of market share. The main source of contamination is leaks in packaging which allow air, moisture and micro-organisms to enter the package.

In the food processing and packaging industry worldwide, there is an increasing demand for cost effective state of the art non-contact inspection technologies that are capable of reliably detecting leaky seals and delivering products at six-sigma.

The proposed new technology will develop non-destructive testing technology using digital imaging and sensing combined with a differential vacuum technique to assess seal integrity of food packages on a high-speed production line.

This technology can also be applied to non-food processing industries where seal integrity is an important factor to the finished product.

Keywords: Vacuum testing technology, Seal Integrity, Packaging Quality

1. INTRODUCTION

Quality assurance is becoming an increasing issue in all the food processing environments, including the snack-food industry, in an age where consumers are aware of the risks associated with spoiled food. Australian companies experienced such issues in their potato chip products because of unsealed packets. Leaky seals cost Australian food industries millions of dollars every year. Cost to wider communities due to contamination is significant.

The most common types of food sealing include cans, bottles, containers, flexible plastic packages and vacuum sealing. Flexible plastic packages are widely used, and are the least expensive form of retaining the quality of the product. These packets can be used to seal, and therefore maximise, the shelf life of both dry and moist products. Examples of foods contained in flexible packets in supermarkets include: sealed pre-cut salad (moist), potato chips and biscuits (dry), dried apricots (moist), pasta (dry) and flavour sachets (moist).
There are many current NDT (non-destructive testing) methods of inspecting and checking the seal of flexible packages best suited to random sampling, and for laboratory purposes.

The three most commonly used methods are vacuum/pressure decay, bubble test, and helium leak detection. Although these methods can detect very fine leaks, they are limited by their high processing time and are not viable in a production line.

Food manufacturers are seeking additional and varying types of in-line NDT machines to service a variety of manufactured products.

Based on current research, three non-destructive in-line packaging inspection machines are currently available. These are the "NPC-501 leak seal inspection system", the "PTI 550 Seal Scan" and the "Ishida TSC-R1530 Seal Checker".

This research developed a cost effective, state of the art technology for accurate evaluation of seal integrity in a high speed food packaging production line, so that accurate decisions on product safety can be made. The technology proposed is based on real time imaging and sensing technology combined with an automated differential vacuum system.

Such a system is not available for the food processing industry in general. Most of the existing methods are unreliable at high production line speeds, and are unable to inspect both clear and opaque packaging materials with the same accuracy [1]. Machines that are available for high production line speed, are not cost effective for real-time, high speed, non-destructive testing of food package.

The proposed system will be able to accurately and reliably classify packets according to the quality of their seal, and will operate at a speed equal to or greater than current production line speeds of the leading potato chips manufacturing company in Australia.

2. LABORATORY DESIGN TESTING

2.1. Mechanical and Electrical

Vacuum testing was completed in the laboratory to verify the ability of packets to expand effectively and efficiently when fully sealed, and also with a broken or faulty seal [2]. Figure 1 shows a sealed chip packet subjected to approximately -20 kPa (gauge) within a laboratory vacuum chamber.

Figure 1: Photograph showing a Sealed Chip Packet inside a –20kPa Vacuum Chamber

The height change of the packets at various vacuum levels is shown in Figure 2 below.

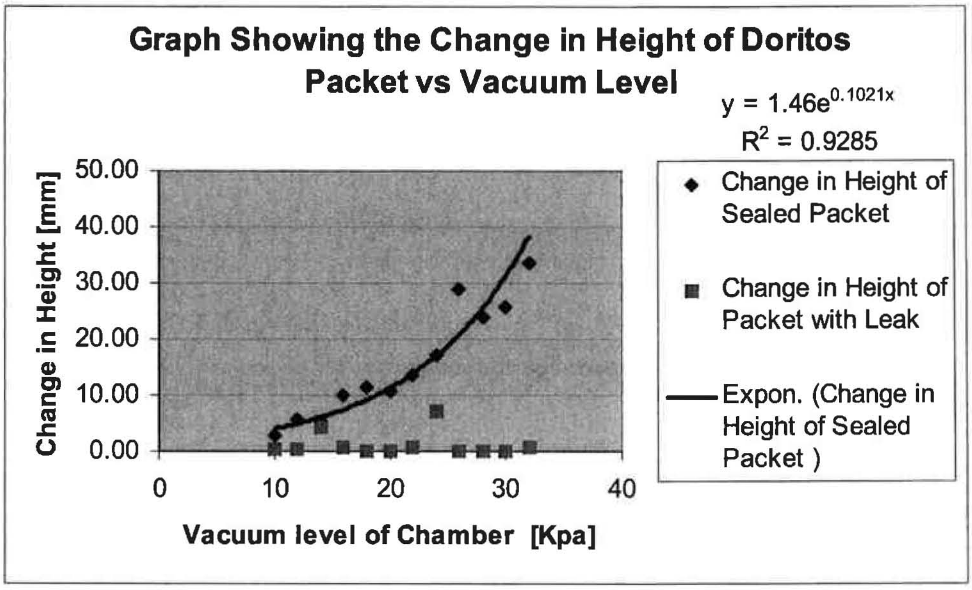

Figure 2: Graph showing Change in Heights of Doritos Packets [2]

Electrical laboratory testing consisted of lighting and a camera, and was set-up against a white paper background to simulate a production environment [3].

Testing was conducted using 50g potato chip packets. Each packet contained a different flavour and had different coloured packaging and slightly different surface visual designs. The test confirmed that packet variety would be acceptable using a camera and light.

The random orientations were used to simulate the likely operation of the Production version of the High-Speed Sensing and Detection System (HSDS) that will receive packets at high speed by dropping packets onto the infeed conveyor belt.

Each test case is composed of two images, a reference image and a vacuum image. The reference image is captured after the packet is placed in the test rig, but before a vacuum is applied. The vacuum image is captured after the appropriate vacuum is applied to the dry box. A graphical representation of the above results can be seen in Figure 3.

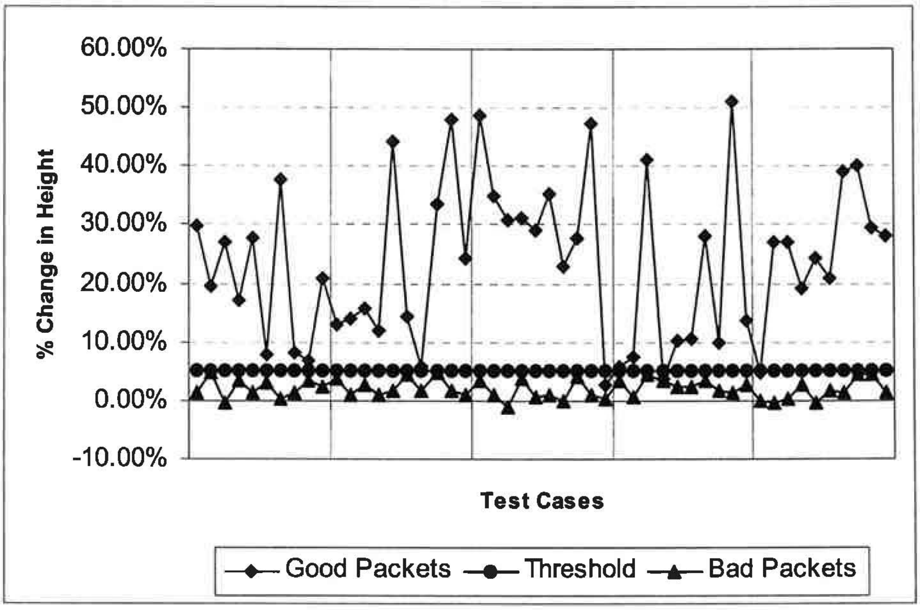

Figure 3: Variation of packet height under differential vacuum conditions [3]

Correlation of leaky seals with heights after vacuum was not helpful. However the difference of heights between room pressure and vacuum helped to distinctly indentify leaky seals.

3. DESIGN

The High-Speed Sensing and Detection System (HSDS) shown in Figure 4 is broken down into the following 13 functions of combined mechanical and electrical requirements as detailed below [2][3]:

- Conveyor Transportation Functions (A)

  The packets will be loaded from the existing conveyor line into the HSDS efficiently without product damage and correct orientation. The packets must also progress through the HSDS without internal product or package damage.

- Vacuum Generation Functions (B)

  The HSDS will subject the packet to a partial vacuum to ensure the sealed packets expand precisely.

- Defect Sensing Functions (C)

  The height/profile of the packet will be assessed at both atmospheric pressure and partial vacuum without contact. Various physical parameters to consider are maximum height and width, change in height, side profile and volume.

- Rejection Functions (D)

  The signal from the decision-making algorithm will be used to physically reject unsealed packets. Reject options include, ram to push packets, air jet/nozzle and selector gate.

- Control and Decision Making Algorithm Functions (E)

  The HSDS will be controlled to ensure leaky packets are rejected. Options include, Discrete Progression and Sensing, Continuous Progression and Sensing, Discrete Progression and Continuous Sensing, Continuous Progression and Discrete Sensing

- Non-Contact Sensing and Decision Making Functions (F)

  The HSDS will require non-contact sensing to determine decision making protocol. Options include, Photoelectric Sensor, Parallel Beam Laser Sensor, Reflex Sensor and Proximity Sensor.

  It was proposed that the packets should be measured with a non-contact sensing method. Non-contact sensing will complete the operation without damage to the integrity of the packet. Although many sensors are available, only those that can provide package height measurement were explored. It was found that the most common type of non-contact sensors are photoelectric sensors. Photoelectric sensors are optically based and are widely used throughout industry.

- Camera Function (G)

  The camera type, placement, numbers and position angle relative to the packet is important in consistent measuring and quality control

  The placement of the camera in the prototype system and hence angle relative to the packet was carefully considered. It was found that the best angle to view a chip packet from is the side when the packet is lying flat on a surface. It is planned in the prototype system that the packets will tend to fall and stabilise in this manner. This angle of viewing provides the greatest visual difference of a packet between normal and vacuum pressure.

  The HSDS should incorporate two cameras in the final design. The first one should capture a reference (before vacuum) image when the packet enters the vacuum chamber (after the packet has stabilised). The second will capture during vacuum image when the packet is subjected to maximum negative pressure.

- Resolution Functions (H)

  The image resolution size will determine the picture quality and repeatability. Several image resolutions were considered in the design. The most common resolution among retail and industrial cameras is 640x480 pixels. The computational processing required in the HSDS is not overly intense and operates relatively quickly on images of this size. Test images revealed that this resolution maintained sufficient detail.

- Grey Scale Conversion Functions (I)

  Images require conversion from RGB to grey scale for packet imaging either through Geometric or Arithmetic mean of component colours. Two methods of converting an 'RGB' image to grey scale were identified. It was found that the use of either method was suitable for prototyping purposes.

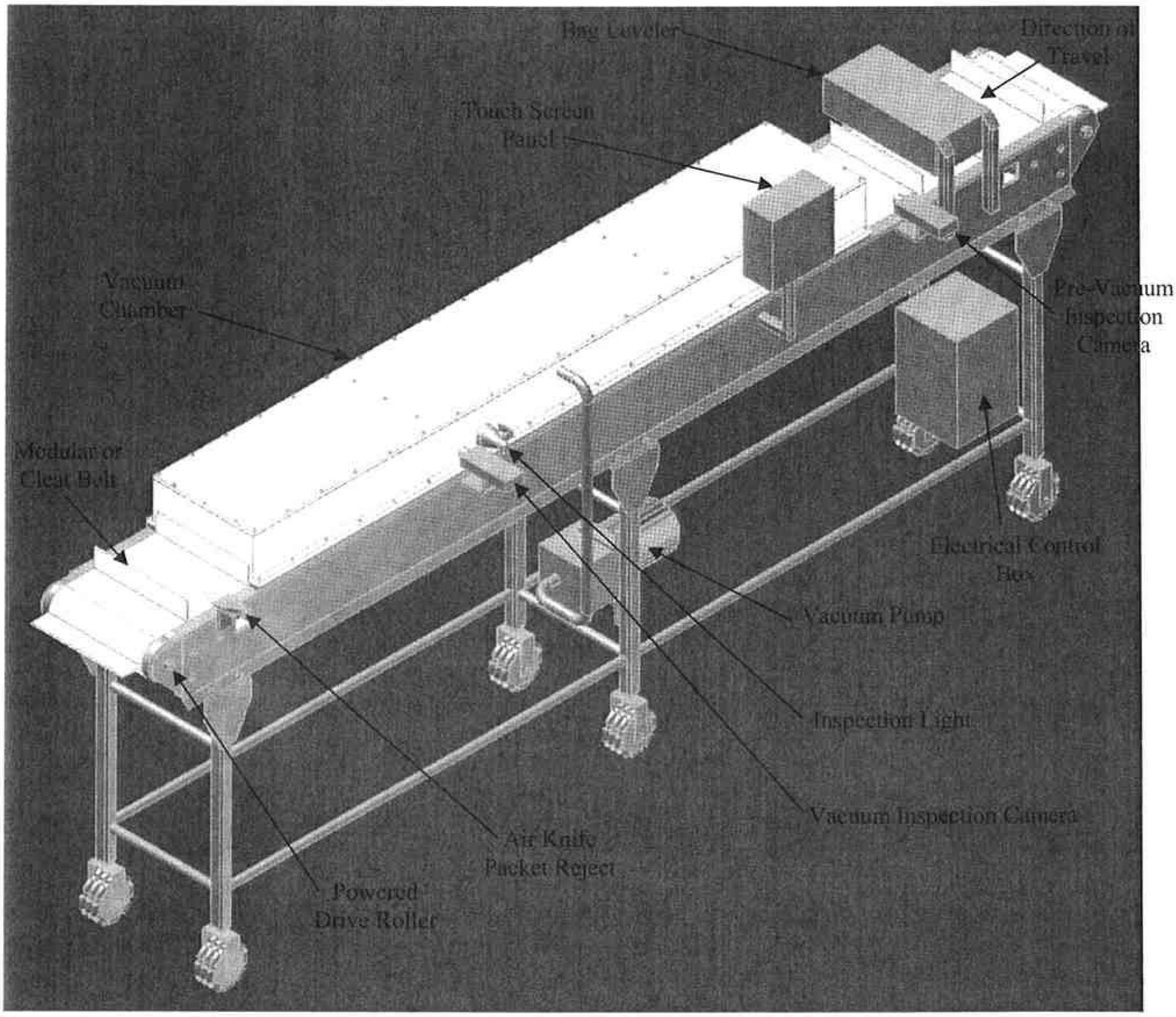

Figure 4: Production Assembly Design

- Background Noise Functions (J)

  A suitable background is required to capture sample images, and when distinguishing the packet profile. The background needs to consider, colour (white), contrast (bright and consistent), sheen (low sheen or non-reflective), finish (plain, not glossy) and surfaces (light coloured and consistent, not busy)

- Lighting Functions (K)

  Suitable background lighting is required to allow suitable vision of the captured sample images. This lighting also improves the packet profile image. Testing was conducted using several different light sources, number of lights and positioning. Two halogen lamps were used and placed just above and either side of the camera directed toward the centre of the image.

- Packet Noise Functions (L)

  Packet film could be a source of disruptive noise. Testing was conducted using several different packet patterns or logos for sources of disruptive packet noise. Testing of a variety of different packets revealed that these patterns had minimal effect on distinguishing the packet or filtering operations.

- Digital Imaging (M)

  This concept worked by taking a photograph of the packet at atmosphere pressure and a photograph inside the vacuum chamber. The two photographs were then automatically compared using image processing and decision was made to reject/accept package (see Figure 5).

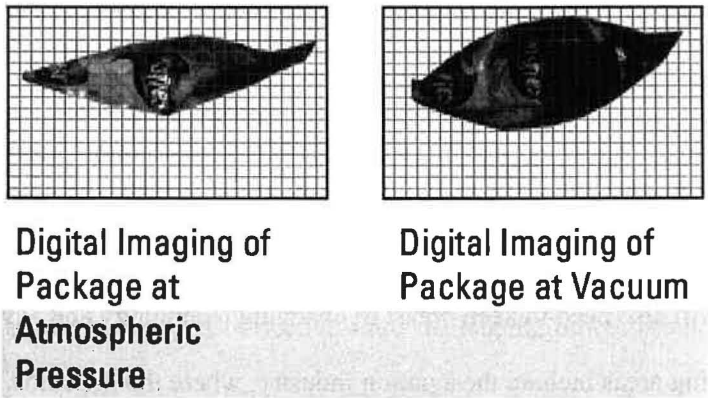

Figure 5: Digital Imaging Concept

The test was based on the change in the number of pixels (i.e. Change in area), containing the packet between atmospheric pressure and vacuum.

3.1. Summary

During the design development process, constraints and considerations became apparent. The six main constraints are discussed below:

Safety: The HSDS must conform to Workplace Health and Safety regulations and legislation of relevant states and territories throughout Australia and the world, and also any specific company technical specifications. The machine shall also not impose undue hazard to either consumers or employees. An important consideration in relation to food processing, is the machine shall not encourage the growth of bacteria or other micro-organism's., and must be easily cleanable during production sanitation periods.

Product Damage: The HSDS shall not damage the product (chips) or packaging, incurring any quality issues or potential loss of revenue.

Accuracy and Precision: The HSDS shall have the capability of rejecting leaky packets at a high level of accuracy and also work within a close tolerance range or limit without wasting too many sealed packets. The accuracy and precision parameter settings shall be adjustable to assist in maximising the cost benefits of installing the machine.

Cost: The initial, operational and maintenance costs of the machine must be economically viable for food processing and packaging companies. It is estimated that the manufacturing costs for the Production

HSDS unit would be around AUD50,000 to 60,000 (€25,000-30,000). This cost includes installation and basic commissioning, but excludes the initial research and development, engineering and drafting costs. It would be anticipated that around AUD20,000 would be required to finalise the engineering and development plus the cost of a proposed prototype unit and trial costs.

Size: The HSDS shall be reasonably compact in design to ensure fitment within an existing production/packaging line. Some companies have space constraints and therefore require careful consideration.

Leak Size: Food Processing Production staff indicated, "The most common leak is approximately 5mm in the sealing area of the packet". Although quantified statistical data regarding leak sizes was not initially available.

4. CONCLUSIONS AND FUTURE WORKS

The digital imaging system for differential vacuum testing has been shown to be effective under controlled tests. Prototyping the unit will verify mechanical and electrical constraints, but also confirm current design procedures and assumptions.

The potential technology could also be utilised in other food processing areas such as, Diary, Seafood, Smallgoods, Meat and Beverages to confirm if other opportunities exist. All areas of food processing offer many future applications with packaging technology constantly changing. The HSDS concept and future Production unit will also need to keep breast of changing technology and advances in packaging.

Other non-food processing areas include the aviation industry, where the inclusion of this type of machine would simulate the environment inside an aircraft. All potential dangerous and harmful goods could be put through the conveyor system to check leak detention and prevent potentially dangerous events from occurring. The application should also be considered in other areas of industry where vacuum testing works effectively.

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