HORIZONTAL APPLICATION OF TAPE SYSTEM (HATS)

A thesis submitted in partial
fulfilment of the requirements for
the degree of

Master of Technology
In
Engineering and Automation

Massey University
Palmerston North, New Zealand

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ABSTRACT

The aim of this course of study was to design and construct a prototype for the automatic horizontal application of adhesive tape, in order to close cardboard cartons containing export meat product. This method of carton closure has been acknowledged as superior, by MAF and the NZ meat industry, to existing methods and it is anticipated that it will significantly reduce the incidence of meat shipments being returned to New Zealand due to evidence of tamper. Project work has been completed at Graphpak Services Limited – a small engineering business servicing the printing and packaging industries.

Key project objectives are identified as follows:

- Resurrection and observation of a historical prototype.
- Design, construction and testing of a hand held model head for testing and poof of function.
- Design, construction and testing of a rotary carton transport assembly.
- Design, construction and testing of a head mounting assembly.
- Design, construction and testing of a carton lidding assembly.
- Individual control systems design for each of the above.
- Integration of the above systems.

- Design of an overall modern multivariable control design model for the integrated system

- Prototype build.

- Commissioning and testing of prototype.

The project was undertaken in a modular fashion. The historical prototype was reconstructed and a new three step tape application process was identified as superior. A new hand held application head was designed, constructed and tested and the principle of operation has a patent pending.

A production model has been scoped and partially designed based on the hand held prototype and is yet to be built. This is to be integrated with a selected Rotary carton handling system that is partially designed.

Appropriate control systems have been identified for each part of the overall prototype and control models are yet to be developed as stand alone models for each module of the prototype. As testing proceeds, an overall modern multivariable control model will be developed and a production machine will be produced.

Other work has included:

- Funding applications for the project.

- Company infrastructure development for the project.

- Marketing of the Horizontal Application of Tape system (HATS).

While the overall project remains incomplete, this dissertation presents the development of the tape application head and the overall machine architecture that have been completed successfully.

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ACKNOWLEDGMENTS

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The research described in this thesis was undertaken onsite at Graphpak Services Limited of Palmerston North, New Zealand.

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- Ministry of Agriculture and Forestry New Zealand (MAF).
- AFFCO New Zealand Limited.
- Charter Packaging Limited.
- Sellotape New Zealand Limited.
- MeatNZ limited.

1 Introduction

Graphpak Services Limited (GSL) was established in 1981 to invent, engineer and deliver technology solutions and services to the printing and packaging industries throughout New Zealand. Servicing of any type of printing or packaging machinery occurs either on site, or at our workshop, by experienced and qualified staff.

Innovative systems and solutions are developed for problems and with consultation, knowledge and experience in the industry, we are able to source and supply the right machinery for the job. We also have the expertise to install and commission new machinery and integrate it with other or existing machinery. If suitable machinery doesn't exist, then (GSL) has the capacity to design and build this equipment using modern computer design techniques and a well-appointed workshop.

GSL has more than 20 years experience in packaging machinery including sales and service of strapping, taping, stapling and gluing machinery. So, 1992 GSL focused on a feasibility study for a horizontal taping machine with the intention of replacing the use of polypropylene strapping. Interest has been shown by both the primary produce processing sector and MAF, in the horizontally applied taping system (HATS) project over the course of study and market research. During this process GSL gave a full time commitment towards producing a prototype. It became evident that the company could not put all their resources into such an activity and there was a need for a party that could assist in providing the right technology and knowledge to make this project a success.

In 2001 technology in industry fellowship funding (TIFF) was applied for and a masterate student was employed to re-address the project in order to develop a production model.

1.1 Facts

Graphpak Services Limited is located in New Zealand's lower North Island at:

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PO Box 7225, Palmerston North.

Email: graphpak_dsl@clear.net.nz

Phone: 64 6 357 9708

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Directors:

- John Bradley (Managing Director)
- Bob McIlhatton (Partner)

Staff:

- 2 Service & Production Engineers.
- Automation and Control Engineer.

1.2 Tamper Evidence

The New Zealand meat export industry has recently been a victim of unscrupulous foreign operators removing meat product from cartons and repacking the cartons with counterfeit product. These cartons then proceed to the original destination where they may or may not be discovered to be counterfeit.

Due to lack of security no clear indication of this form of tampering has been provided causing recipients to reject shipments of New Zealand product based on, often unreasonable, suspicion of cartons being tampered with. Sometimes a container load of cartons is rejected on the basis of only a few cartons suffering some general handling damage. (See Appendix A.9 Pgs 80)

These shipments of meat are returned, at New Zealand's expense, and then redistributed on the domestic market!

Commonly, the various cuts of meat are loaded into cardboard cartons and a lid is strapped into place using polypropylene strapping material. Official Ministry of Agriculture and Forestry (MAF) adhesive labels are placed onto the carton, bridging the seam created between the lid and the base of the carton while also covering the strap that passes this juncture. This is the sole current means of providing evidence of tamper using this closure system.

There are pitfalls associated with this method of tamper evidence. These include

- MAF labels (seals) are vulnerable to rough handling often being damaged or partially removed by as much as only rubbing one box against another (often entire container loads of products are rejected based on this alone).

- Strapping the carton does not make for a rigid and uniform package causing the cartons to be difficult to handle and stack and increasing the risk of MAF seal damage.

- The strapping does not secure the lid to the base of the carton at the corners, which allows access to the contents of the carton at these points without disturbing the MAF seals.

1.3 Environmental

The Meat, Fish, Butter, Cheese and Fruit export industries are subject to environmental regulations to limit the use of non-recyclable or non-reusable packaging imported into Europe. By mid 1995 all European Community countries had some restriction on the use of non-recyclable materials present in packaging sent to the European Community. These materials include

- Polypropylene.
- Nylon and P.E.T. Straps.
- Hot melt adhesive.
- Plastic Liners.
- Metal Staples.

All the above incur punitive recycling fees **Re**cycling **Sy**stem (RESY) because they require expensive processes to render them recyclable. (See Appendix A.3 Pgs 71).

These fees become a tariff barrier to our exports and there is major concern within the primary export industries that these barriers are a way in which the markets can get around the General Agreement on Tariffs and Trade (GATT) free trade accord, which allows free access for our New Zealand products but does not apply to the packaging. (See Appendix A.2 Pgs 69).

Currently most fish and meat cases exported from New Zealand are cardboard cases held together with polypropylene straps or hot melt adhesive. The company responsible for importing these cases into the European Community is expected to recover all the used cases and closures, separate out the polypropylene straps, liners or adhesives and recycle the materials separately. Therefore it is the closure method that attracts the highest Tariff (RESY).

There are other environmental issues involved with this method of closure including

1. The strapping system does not seal the closure and a plastic liner is introduced to seal the contents of the box to inhibit freezer burn and protect the board used for the carton from the inherently damp contents.

2. Strapping, hot melt glues, metal staples, board, and the plastic liner are incompatible in terms of recycling and require separation to be recycled effectively.

3. Strapping, when carelessly discarded, has a reputation as being an environmental hazard to wildlife. A scenario of a fishing boat sliding the loops of strap off a bait carton and tossing it over the side typically represents this. Marine animals often become entangled in these loops of strap that can ultimately cause the unnecessary death of these animals. Nor does the strap discriminate between an endangered or non-endangered species of animal.

4. The hot melt adhesive system of closure consumes larger amounts of energy and is relatively expensive.

Within the interests of our primary exports and extensive research on the subject - Graphpak have developed an alternative closure method that attracts the least amount of Tariff being applied.

1.4 Principles

The tape is applied horizontally around the carton seam with the width of the tape applied evenly to the bottom side of the lid, the bottom edge of the lid and the adjacent side of the bottom of the carton as illustrated. (See Fig 1).

(Carton with applied tape)

Figure 1

The proposed method of closure employing taping will produce a sealed package eliminating the need for polypropylene strapping and plastic liners, providing the board used to make the carton has an aqueous coating. The system will also improve recyclability as the two remaining substrates are cardboard and cellulose based tape. In terms of recycling, these are compatible with each other.

The structural integrity of a HATS closed carton is superior due to the inclusion/lamination of the lid as an integral part of the box.

If as is the case with strapping or gluing, the sides of the base of the box are unsupported then the sides are prone to buckling and bending when the full box is being handled. Under these circumstances, the neutral axis of bending is effectively within the base plane of the box and there will be minimal resistance to bending.

If the sides of the lid are HATS taped to the sides of the base, then the sides are less prone to buckling and the neutral axis of bending is effectively shifted halfway up the sides of the closed box. This gives the box a greatly improved second moment of area and an improved structural integrity.

Fish, venison, sheep meat, goat meat, fruit and vegetable packaging could also benefit from the new method – particularly with the improved structural

integrity of the package giving better protection to contents that could be easily bruised or damaged.

Palletizing, freezing, storage and shipping are greatly improved, as the package becomes brick.

Presently in New Zealand, there are approximately 700 polypropylene strapping machines being used by our various export sectors. It is anticipated at least one third of these machines will be ultimately replaced by an alternative method of case closure. Benefits of this method of closure as previously described are:

- The case becomes tamper evident.
- Improved structural integrity.
- Can be sealed to eliminate freezer burn without a plastic liner substrate.
- Conforms the shape of the carton to a uniform standard.
- Conforms to current requirements for recycling.

The principal of this type of closure is unique in as far as research at this time has shown throughout the world. While the relevant industries have an interest, this taping principal requires an appliance which, by the nature of the industries targeted, needs to be a versatile to cope with varying case sizes and types. Research has been carried out to quantify the design of an appliance incorporating variations for industry types. Because of the nature of the industries these machines will be utilised in, the design is simple and reliable, automatic and adaptable and be able to be serviced by in-house engineers.

It is foreseen that should New Zealand be successful in having product exported into key markets with this type of closure, the export potential of this system to countries such as Chile, Argentina, USA, Australia and other primary producing countries would be the next step after commercialisation.

1.5 Thesis Content

The content of this thesis will focus on the following areas:

1. Analysis of the infrastructure of GSL and the difficulties in tackling a project of this nature and size and the identification and development of a sustainable solution.
2. Market research, literature research and development of the functional requirements to produce a machine that will effectively fill the need for a system of taping cases to meet the needs outlined.
3. The development and selection of a suitable overall conceptual mechanical model.
4. Development of the project plan.
5. Overall machine architecture, synopsis of operation and identification of suitable control system models.
6. Technical development of the tape application head and analysis of adhesive tape properties.
7. Identification of funding sources for the research and development (R&D) and the work undertaken to secure suitable funding.
8. Revision of the project progress at the conclusion of this TIFF period.

1.6 Planning

Graphpak Services Limited (GSL) is a small engineering business servicing the printing and packaging industries. At the beginning of the masterate period, GSL staff consisted of two trade service engineers and the owner operator. The business operated out of workshop on Bennet Street in Palmerston North. The main workshop plant machinery consists of:

- Two lathes.
- Milling machine.

- Welding bay (Gas MIG and TIG).
- Sundry grinding and cutting machines.
- Sundry Hand tools and power tools.

The machinery listed enables GSL to manufacture most replacement parts required for maintenance and repair of printing and packaging machinery (often it is less expensive for Graphpak to manufacture a part than to source an original part). Repairs to machinery are undertaken both on-site and in-house.

One off design and build of machinery items are undertaken by Graphpak. Since the masterate has begun, these have included:

- One automated paper pick and place machine with pile lifter.
- One automated stapling machine for carton assembly.
- One die cutting machine for perforating hardboard containers for bumblebee packaging.

These machines have been completed and are currently working well in their respective environments. The typical procedure for tackling these projects is ordered as follows:

1. Approach by customer for a solution.
2. Discussion between owner operator and customer to develop a concept solution.
3. Development of concept drawings, lead time and quote by owner operator for customer.
4. Go ahead from customer.

5. Discussion about and amendment of conceptual drawings to suit, with engineering staff at GSL.

6. Project is completed from concept, based on trial and error and the past collective engineering experience of the staff.

This procedure is effective in terms of a result for the customer but in all of the above mentioned cases, cost and lead time overruns have been evident. The cost overruns have been directly proportional to the lead time overruns exposing the initial engineering time estimates to be underestimated. The procedure however is still suitable for smaller projects and is useful and fast where engineering experience can be substituted for significant amount of research and planning. It leads to an individual or small business being able to forgo costly planning procedures (Draughting, project management, consultants, industrial design and etc.) and manufacture relatively simple, and sometimes quite complex, solutions to a problem.

Larger projects do require more formalised planning and a conclusion drawn here is that the above procedure should be rearranged to include item five: "Discussion about and amendment of conceptual drawings to suit, with engineering staff at GSL" before item three: "the development of concept drawings, lead time and quote by owner operator for customer" occurs. It would also be useful to develop a time line with, overrun buffers worked in, and to set goals and milestones for the project. The extent of the planning required is dependent on the complexity of the project.

1.7 The HATS project

The scale of the HATS project is acknowledged as large and there is little existing previously engineered technology available to bypass larger component assemblies of the machine development. Thus it is important that the infrastructure of GSL is adjusted to take advantage of up to date planning, design and management tools and to import a specialist skill base to complete the project. Work here has included:

- Identification of specialist skills required.
- Purchase of up to date computers.
- Networking of the computers.
- Introduction of:
    - Cad software.
    - Project management software.
    - Database spreadsheet and word processing software.
    - Internet enable software.
- Institution of systems for information management.

Consultation with potential customers.

To develop a machine, it must suit the environment that it will operate within. To assess the operating environment, visits to and consultation with various potential customers have served to help produce the list of functional requirements for the machine development. These potential customers are seen as part of New Zealand's meat exporting industry. The main players in this market are identified as Richmond's and Alliance, New Zealand's two largest meat exporters. However, the operation is mirrored in smaller

exporting companies such as Taylor Preston and Manawatu Beef Packers. The processes in these smaller companies are considered representative in terms of:

- Factory layouts and space available.
- Rates of product throughput.
- Hygiene requirements.
- Operating and maintenance requirements.
- Required reliability.

Manawatu beef packers have offered their facilities to GSL to use as a test bed for development of the closure system.

1.8 Consultation with MAF

The proposed carton closure system has been outlined to MAF representatives and they have endorsed the closure system as a panacea to the tamper evidence problems the New Zealand meat export industry is experiencing. (See Appendix A.9 Pgs 80).

1.9 Potential market for the system

This section clarifies the number of "20kg cartons of sheep and beef meat" (export product) to be closed for export annually and hence the required amount of adhesive tape.

Carton size will vary for different cuts and types of meat but the assumption has been made that spreading the annual tonnage of non carcass meat exported from New Zealand (NZ) into 20kg cartons will give a good conservative indication of the overall length of tape required to make these closures.

It is anticipated that initially 40% of the closures will be by the proposed taping method with this percentage increasing as time goes on.

These figures have been furnished by Meat NZ and AFFCO NZ Fielding. The Meat NZ figures are provisional and represent all sheep and beef product exports by all NZ exporters.

The AFFCO NZ Fielding figures are used to calculate the ratio of tape application machines to tonnes of sheep and beef meat, required to close export product.

It is acknowledged that the AFFCO Fielding plant, used as the model for this calculation, is a mid sized plant and many smaller plants throughout NZ will have a larger ratio of machines to tonnes of export product closed. Likewise fewer larger plants will have a lower ratio of machines to tonnes of export product closed. Thus the calculated 96 machines required for national export product closure is an absolute minimum figure.

However, the number of product closures remains the same requiring the same amount of tape regardless of the ratio of closure machines per tonne.

The amount of sheep and beef meat exported from NZ for the period Oct 2000 – Sept 2001 was 1,091,771 tonnes (provisional) consisting of 356,813 tonnes of sheep meat, 376,756 tonnes of sheep offal and 358,202 tonnes of beef meat including offal. 35,798 tonnes (representing 3.3% of total exports) of this is exported in carcass form leaving 1,055,973 tonnes of meat for export product closure by the proposed method.

Given that each export product closure requires 1.8m of adhesive tape, and that 1,055,973 tonnes equates to 52,798,650 export product closures, the resulting potential annual adhesive tape requirement is 95,037,570m or some 95,000km of tape annually. It is expected that 40% of this potential will be realized initially i.e. 38,000km of tape applied by 38 or more closure machines.

These figures by MAF figures based on the number of carton seals allocated during the same year. Further study to clarify these figures, on a works by works basis, is currently underway. (See Appendix A.8 Pgs 78).

1.10 Current methods of carton closure

1.10.1 Current adhesive taping systems

Method outline

1. This system is used mainly to close RSC type cartons. These are identified by closure flaps both top and bottom that fold together to meet at the longitudinal centre line of the carton. The seams are then taped for closure.

Table 1 (Advantages and Disadvantages of Adhesive Taping Systems)

Current Adhesive Taping Systems	
Advantages	Disadvantages
Environmentally friendly	Currently used only on level surfaces
Good carton structural integrity	Bottom closure seam is subject to failure
Extra substrate easily recycled	MAP seals are vulnerable and are easily damaged in transit.
	Erected flaps hinder carton loading

This method of closure is considered unsuitable for meat packaging as:

1. Carton structural integrity is poor with regard to meat product.
2. The erected flaps hinder carton loading.

The bottom carton closure seam is likely to fail due to the nature of the contents.

1.10.2 Hot Melt Gluing

Method outline

A bead of hot melt glue is applied to the lid flap or side of the carton. The lid flap is contacted with the side of the carton before the glue is cured and is held in position until the glue sets.

Table 2 Advantages and Disadvantages of Hot Melt Gluing

Hot melt gluing	
Advantages	Disadvantages
Environmentally friendly	High energy use to heat glue
Good carton structural integrity	Slow curing time
	Expensive system
	MAP seals are vulnerable and are easily damaged in transit.
	High maintenance and messy system
	Extra substrate to separate for recycling

1.10.3 Polypropylene Strapping

Method outline

The carton is filled and closed. To complete closure, four polypropylene straps are tightened around the carton (one each end and one each side), are heat sealed and released. Table X outlines key advantages and disadvantages for this method of closure.

Table 3 (Advantages and Disadvantages of Polypropylene Strap)

Polypropylene Strap	
Advantages	Disadvantages
High strength	Environmental issues
Useful for handling cartons	Cuts into carton
Inexpensive	Distorts carton
Simple to apply	MAF seals difficult to apply and are easily damaged in transit.
	Manual operation
	Extra substrate to separate for recycling

The three current systems closure addressed here are commonly used in the packaging industry. These closure methods have been investigated in order to make certain that they cannot be used or modified to achieve the same ends as the HATS project. The hot melt gluing and strapping systems fail to address the issues of tamper evidence and this alone precludes further development. The current system of taping closure applies to a type of carton that is widely considered unsuitable for the meat packaging industry and further development for this purpose is not useful. This system of closure may still use the specially marked tape for closure in other export packaging industries where the nature of the contents is suited to this type of carton.

1.11 Objectives of the thesis study

1. Identify a method of carton closure for the New Zealand meat export industry that offers security and tamper evidence that will significantly reduce the amount of export product that is returned, due to perceived evidence of tamper.

2. Analysis and development of GSL infrastructure according to the execution of the development of the carton closure project.

3. Design, specification and manufacture of a prototype carton closure machine.

4. Installation and commissioning of the prototype machine and development of a production model.

1.12 Summary of Thesis research outcomes

A new system of carton closure has been identified that will significantly reduce the incidence of export product-shipments being returned to New Zealand due to evidence of tamper. The system is based on preliminary design ideas that have been identified and developed in consultation with MAF and the NZ meat processing industry. The basis of the system is the Horizontal Application of Tape System (HATS) to the seam, created between the lid and the base of a carton.

- This system precludes entry to the contents of the carton by way of delamination of the cartons surface upon removal of the tape (clear tamper evidence).

- It has the added advantage of being more robust, than other closure methods, under all handling conditions significantly reducing instances of perceived tamper.

- Recyclability of packaging substrate is significantly improved allowing increased compatibility with end markets and, subsequently, reduced costs to the NZ export industry.

MAF and the NZ meat industry have given approval in principal to the system and one major NZ meat exporter has formally ordered the installation of one such system for mid 2003. This will consist of a two prototype machines to swap in and out of production as assessments and modifications are made to the machines.

Design and specification has proceeded in a modular fashion. The head design was first proven by design and manufacture of a hand held application head. Documentation was prepared and a patent was applied for. This head has been used to demonstrate the HATS principle. A system model has been designed and awaits manufacture. This will incorporate a stand alone control

system to be later integrated into an overall modern multivariable control system for the complete production model of the machine.

Carton handling has been addressed and preliminary designs exist based on a rotary handling system. Again, this will incorporate a stand alone control system to be later integrated into an overall modern multivariable control system for the complete production model of the machine.

A prototype is yet to be built but the existing design material has been handed over to a facility in Finland with the infrastructure and in-house design and manufacturing ability to complete two prototype machines to meet the mid 2003 deadline for installation and testing.