SECTION D
Meat Processing

APPLICATION OF AUTOMATION AND ROBOTICS TO PIG SLAUGHTERING

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Summary

The Danish meat industry has special requirements for automation and mechanisation due to high labour costs and the increasing demand for improved working environment and improved animal welfare.

The object of this paper is to describe a realistic proposal for an automated pig slaughter line three to five years from now.

The proposal is based on the existing slaughter processes in Denmark and the automatic equipment either already developed or under development.

The following equipment is described:

- An automatic lairage system developed by the Danish Meat Research Institute. The system improves animal welfare and working conditions. The system is marketed by SFK Meat Systems.

- An automatic equipment for group-stunning of pigs. The equipment has been developed in cooperation between the Danish and the Swedish Meat Research Institutes and will improve both animal welfare and working conditions.

- A scalding system based on steam condensation as a more aesthetically appealing alternative to traditional scalding vats or shower cabins. The system is marketed by SFK Meat Systems.

- A test system for automatic gambrelling of pigs developed by Centre for Construction and Mechatronics in Holland.

- A test system for rind treatment based on ice blasting. The system is developed by the Danish Meat Research Institute and improves the hygiene compared to the existing system.

- An automatic machine for fat end loosening developed by Centre for Construction and Mechatronics, and an effective method to seal the fat end using frozen steel plugs, developed by the Danish Meat Research Institute.

- An automatic carcass opening machine developed by Centre for Construction and Mechatronics.

- A demonstration model of an automatic evisceration system developed in an European Union funded project with the Danish Meat Research Institute as coordinator and with participation from University of Bristol and Ricardo Hitec Ltd. from the UK, Siemens from Germany, and Risø National Laboratory from Denmark.

- An automatic back scoring and finning machine under development in cooperation between the Danish Meat Research Institute and Danfotech.

- A machine for automated loosening of leaf fat developed by Durand International in France.

- The automatic classification centre used on all Danish pig slaughterlines, developed by the Danish Meat Research Institute and the newly developed Auto-FOM classification system from SFK Technology based on ultrasonic measurements.

- The slaughterline data network system developed by the Danish Meat Research Institute and installed at all Danish pig slaughterhouses.

Introduction

The Danish meat industry has special requirements for automation and mechanisation due to high labour costs and the increasing demand for improved working environment and improved animal welfare. The export orientation of the Danish meat industry also creates a need for good hygiene and long storage life of products for overseas destinations.

In the following I will present my proposal for an automated slaughterline three to five years from now. The proposal is based on the existing slaughter processes in Denmark and the automatic equipment either already developed or under development.

Automatic Lairage System

Traditional lairage systems hold large groups of pigs. This makes it difficult for plant personnel to move pigs into and out of the lairage without using some force, simply because pigs blocking the way cannot easily be reached. Moreover, fighting, which is caused by a few very aggressive animals, can involve many pigs thus giving rise to an increased incidence of skin damage as well as preventing resting behaviour.

These observations formed the basis for the Danish Meat Research Institute's development of a fully automatic lairage system aimed at keeping pigs in small groups of 15-18 pigs, corresponding to the compartment sizes on

most Danish transport vehicles. The system was designed to utilize normal pig behaviour at all stages to reduce the use of force as much as possible.

The small pen system consists of a series of flap gates with vertical bars. 15 pigs are moved from the off-loading bay to the pen, and during this stage the live inspection is carried out by a veterinarian.

A push-hoist gate automatically moves behind the pigs until a point is reached that allows a flap gate to close. The push-hoist gate is then raised and moved back to collect the next 15 pigs, and so on. As the flap gates close, a trough is automatically lowered and water made available to the pigs. Built-in ventilation ducts in the pen walls optimise ventilation at pig level. Emptying the pens follows a similar procedure as filling the pens.

A comprehensive test of the system showed a significant improvement of animal welfare, compared to a traditional lairage system, resulting in reduced skin damage and blood splashing. Moreover, the required number of workers in the lairage area is reduced. The system is in operation at one slaughterhouse in Denmark, where the slaughter rate is 800 pigs per hour. The system is marketed by SFK Meat Systems in Denmark.

Automatic Equipment for Group-stunning of Pigs

The solution of the problems in the holding area has highlighted the difficulties that still remain with the race immediately prior to the stunning equipment. It is apparent that pigs are highly stressed in this area where force is being used to maintain the flow of pigs to stunning.

To solve this problem the Danish and Swedish Meat Research Institutes are collaborating to develop an optimal system for transferring pigs from the holding pens to stunning. The principle of the system, which assumes that pigs are held in small groups of 15-18 pigs in the pens, is the same as for the automatic lairage system, i.e. that normal pig behaviour should be utilised at all stages to reduce the use of force as much as possible.

The total system comprises four main elements:

- A system where groups of 15 pigs divide themselves into three groups of five pigs each. The small groups are separated from each other by slide gates controlled by a vision system measuring the floor area covered by pigs.

- A system of push gates and hoist gates for automatic transfer of the small groups to the stunning equipment.

- A CO_2 dip lift stunning equipment with 3 boxes.

- A conveyor system for orientation and separation of the stunned pigs before shackling and sticking.

A full scale prototype with a capacity of 400 pigs per hour has been built at a plant in Denmark and has been preliminarily tested. The results show that pigs move easily through the dividing system and can divide themselves into smaller groups at a rate significantly higher than the required 400 pigs per hour. The transfer system and the stunning system also work satisfactorily.

At the moment we are optimising the conveyor system between the stunning equipment and the shackling area in order to establish the best possible working conditions for the shackling operator.

The final test of the total system under normal production conditions is expected to be completed by the end of this year.

Shackling and Sticking

Technically it might be possible to automate both the shackling and sticking operations. However, from an animal welfare point of view I think these operations should remain manual.

Scalding and Dehairing

Traditionally scalding of pigs is done by immersing the bled carcasses into scalding vats filled with hot water or by showering the carcasses with recirculated water in shower cabins. In both cases the water will become polluted by dirt from the surfaces of the pigs as well as by urine and faeces from the pigs.

An aesthetically more appealing method is steam scalding, where the heat is transferred to the pig through condensation of the steam on the surface.

The Danish Meat Research Institute has, in collaboration with SFK Meat Systems, developed and tested a condensation system for hanging scalding with a special humidifier able to maintain a constant temperature and 100% air humidity under varying loads.

Compared to a scalding vat, the steam scalding system consumes both less energy and less water.

As to the dehairing process, the existing method will continue to be used.

Gambrelling

Centre for Construction and Mechatronics has developed a test system for automatic gambrelling of the hind legs of the pigs. The system holds the hind legs of the dehaired pig in a fixed position and sticks a penetration pin and a penetration tube through the hind legs where the hooks of the gambrel are to be placed. Then the points of the gambrel hooks are guided through the hind legs with the help of the penetration tubes.

The equipment is still not fully developed, but according to information from Centre for Construction and Mechatronics the system should be ready within 1-2 years.

Singeing, Flaming

The existing methods will continue to be used.

Rind Treatment

In existing slaughterhouses the carbonized outer skin layer of the pigs is scraped off in automatic scraping machines and the rind is polished with brushes.

From a hygiene point of view this process is questionable as both scraper blades and brushes distribute bacteria from the throat and rectum area of the pigs to the entire rind surface. Furthermore, a cross contamination between individual carcasses occurs.

The Danish Meat Research Institute has developed a method, which is much more hygienic. This method could either replace, or work in combination with, the existing one.

The new method is based on ice blasting. Small ice particles are hurled at great speed from a mechanical centrifugal acting impeller against the surface of the carcass, knocking off the carbonized layer of the rind.

Tests carried out with a small scale test equipment have shown that the concept works and that a satisfactory process result can be achieved. Furthermore, a cost calculation has shown that the total cost per pig is approximately the same as for the current process.

Fat End Loosening

A machine for automated fat end loosening developed by Centre for Construction and Mechatronics has been installed and tested in a Danish slaughterhouse and has recently been approved for normal production. The machine performs the following processes:

-   Loosening the fat end
-   Cleaning the rectum by a rinsing and sucking system
-   Splitting the pubic bone
-   Dividing the hams
-   Cleaning the knives with hot water.

Once the fat end has been loosened, it drops into the abdominal cavity of the carcass. Microbiological analyses have shown that it doesn't result in contamination problems.

Should complete guaranty against the transfer of intestinal organisms to the rest of the carcass be required in the future, then the Danish Meat Research Institute has developed an effective method to seal the fat end.

The method is based on the adhesive effect of a frozen steel plug inserted into the anus.

The steel plug is designed like a thermos flask to ensure that the accumulated cold only is transferred where the plug is to adhere to the anus. Before the plug is applied, it is chilled in liquid nitrogen; it is then inserted into the anus immediately before the carcass is moved into the singeing oven. The singeing process sterilizes the surface of the carcass, and the frozen plug remains in the fat end until the guts set is removed from the carcass on the clean slaughter line.

The system has been tested under production conditions over several days with very satisfactory operational and microbiological results.

Carcass Opening

Centre for Construction and Mechatronics has also developed a machine for automatic carcass opening. One machine is currently being tested in a Danish slaughterhouse. The machine performs the following processes:

-   Catching and centering the carcass
-   Pushing the front legs aside
-   Penetrating the pharynx
-   Cleaving the breast bone
-   Cutting open the abdomen
-   Rinsing the tools with hot water.

The production test in Denmark is not yet completed.

Evisceration

A demonstration model of an automatic evisceration system has been developed in a project financially supported by the European Union BRITE programme with the Danish Meat Research Institute as coordinator and with participation from University of Bristol and Ricardo Hitec from the UK, Siemens from Germany and Risø National Laboratory from Denmark.

The carcass is fixed on a frame moving to five stations on an oval track: An entry station, a measuring station, a robot station, a viscera pulling station and an exit station.

In the measuring station the carcass is measured by a 3D vision system to determine the guiding points for the evisceration processes. The information captured here is sent to the next station, the robot station.

The robot loosens the gut-set from the back with a connective tissue cut. This makes the gut-set drop and hang down in front of the diaphragm.

Then another tool cuts out the diaphragm and the lungs which also drop. The gut-set and pluck set are now hanging outside the carcass by the oesophagus and trachea.

The next station is the viscera puller. This station is only used when the lungs are not loosened and dropped in the robot station, for instance if the pig has suffered from pleurisy.

The demonstration model is installed at the training slaughterhouse of the Danish Meat Trade College and comprehensive tests have been carried out with promising results.

Further development of the system is planned and a prototype is expected to be ready for testing under normal production conditions in 1997.

Back Scoring and Finning

All Danish pig carcasses are back scored and finned prior to carcass splitting in order to avoid damage to the loins by the splitting saw. The Danish Meat Research Institute collaborates with the Danish firm Danfotech on the development of an automatic equipment for this process.

A prototype has been built and installed at the training slaughterhouse of the Danish Meat Trade College, and preliminary tests are now being carried out. It is planned to move the equipment to a production plant in a couple of months for testing under normal production conditions.

The machine performs the following processes:

- Holding the carcass in a fixed position
- Prescoring
- Cutting free the broad spinous processes
- Opening the cartilage capsules of the spinous processes
- Back finning
- Cleaning the tools with hot water.

The production test of the prototype is expected to be completed by the end of this year.

Carcass Splitting

The existing automated carcass splitting machine of the sawing type has been in operation in Danish slaughterhouses for more than ten years and will continue to be used in the future.

Loosening of the Leaf Fat

A machine for automatic loosening and pulling of the leaf fat has been developed by Durand International, France.

The machine performs the following processes:

- Detecting the position of the carcass
- Locating and grasping the leaf fat
- Holding the carcass fixed while pulling
- Pulling and loosening the leaf fat.

This machine has not yet been tested in Denmark. However, we are planning to test it in the near future.

Carcass Classification

A classification centre for automatic measurement and calculation of the meat content as well as automatic branding of health and grade stamps was developed by the Danish Meat Research Institute in the mid 1980'es. 31 centres were produced and installed at the Danish slaughterhouses during 1988-89.

The classification centre consists of a number of measuring and handling stations.

In the in-station the carcass is transferred to a fixture that leads the carcass through the centre.

In the anatomic measuring station the position of the front leg and the pubic bone is determined by two mechanical detectors. These measurements are used in the probe measuring station to adjust the three probe carriers. Then seven optical probes are inserted into one of the half carcasses, and the probes record the thicknesses of fat and meat. At the branding station the health and grade stamps are branded on both carcass halves.

The original system to interpret the reflection profile from the optical probes was a conventional pattern recognition system. That system has now been replaced by a profile interpretation based on the utilisation of neural networks. Similarly, the recorded thickness measurements are evaluated and adjusted through a comparison of all measurements by another neural network.

The utilisation of neural networks has made it possible to reduce the number of probes from the original 17 to 7 while still maintaining the calculation accuracy for the meat content. Fewer probes means a considerable reduction of the maintenance costs for the classification centre.

A new development from the Danish firm SFK Technology, the Auto-FOM system, which i. based on non-invasive ultrasonic measurements for carcass classification, might be a future alternative to the described system.

During the next few months the Danish Meat Research Institute is going to test the Auto-FOM system in cooperation with SFK Technology. The test will be rather comprehensive, and it will include a comparison with the existing system.

Slaughterline Data Networks

As the carcass proceeds on the slaughterline, a number of important data are measured and recorded. These data are used for e.g. sorting the individual carcasses into classes. This makes it possible to optimize the utilisation of raw materials in the subsequent production of various finished products.

To collect, process and exchange these data, the Danish Meat Research Institute has from 1990-92 developed and installed a data system which is identical for all Danish slaughterhouses. The systems concept was decided on in the analysis "CIM in the Pig Meat industry" carried out in 1989.

The individual sub-systems are connected to industry networks of the Bitbus type from Intel Corporation, and a Cell Controller has been installed for the central storage and coordination of all data from the slaughter area (1-4 slaughter lines).

A Line Controller on each slaughter line collects and exchanges data from the following equipment:

- PLC systems controlling the line flow
- Automatic classification centre
- Manual back-up classification system
- Weighing-in terminal
- Meat inspection system
- Equipment for registration of fat samples from entire male pigs.

Connected to the cell network is the Cell Controller, the Line Controller, analysis robots for analysing fat samples from entire male pigs, and a sorting computer for sorting carcasses to the chilling rooms.

The connection between the physical flow of carcasses and the data flow is ensured by an identification system mounted on the gambrels on which the carcasses are transported. The following three systems are used:

- Bar code system
- Radio tag system
- Vision system.

Conclusion

In my opinion, the present state of development indicates that technically we will be able to establish highly automated slaughter and dressing lines with improved working conditions, improved hygiene, and improved animal welfare in three to five years. Preliminary cost/benefit calculations based on one shift operation and estimated investment costs also indicate a reduction of the total slaughter costs due to a significant saving of labour costs.