2-L3

Development of "HAMDAS" Fully-automated Fresh Pork Ham Deboning Machine

Mayekawa Mfg. Co., Ltd., Advanced Food Machinery Laboratory

I. Abstract

The meat processing industry in Japan is regarded as a typical labor-intensive industry. Due to this labor-intensive character, many meat processors have been seeking systems that rely less on skilled labor in order to achieve production cost reduction. In particular, the deboning process has been highly dependent upon skilled workers, so this has been a particular target process for development of mechanization and automation. Taking advantage of advanced technologies, developments in this respect, it is possible to achieve considerable improvement in safety, hygiene and sanitation, not to mention productivity.

Against this background, Mayekawa Mfg. Co., Ltd. has been carrying out ongoing research and development of a fully-automated fresh pork ham deboning machine. A prototype machine, the "HAMDAS", which is a semi-automated fresh ham deboning machine, has been created which we believe can eventually be developed into a fully-automated device. The following report presents the results of development along with comments on test operation results.

II. Manual Deboning Procedure for Fresh Pork Ham

Before explaining the HAMDAS deboning system, it is necessary to define the manual procedures for deboning fresh bone-in pork ham.

1. Definition of Fresh Bone-in Ham

Fig. 1 shows the structure of a fresh bone-in ham. The target portion is identified by the orange color.

2. Manual Deboning Procedure

① Cut the Achilles tendon and strip off the muscle of the hind shank along the hind shank bone.
② Cut off the exposed hind shank bone at the knee joint.
③ Loosen the tail bone on both sides.
④ Strip off the muscle remaining on the hip bone by pushing toward the tail bone, then loosen the hip bone while exposing its surface.
⑤ Gouge the muscle in the cavity of the pubic bone and cut off the hip bone from the inside ham.
⑥ Cut the hip joint out and cut into the back side of the hip bone, then remove the hip bone and tail bone.
⑦ Cut up the muscle along the membrane between the inside ham and the knuckle.
⑧ Cut up from the bottom of the leg bone joint and remove the leg bone by pulling on it at the end.
⑨ Remove the kneecap bone.

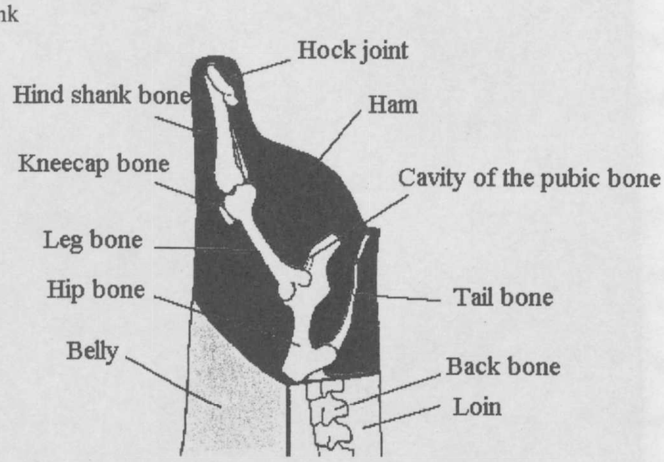

Fig.1. Structure of fresh bone-in ham

These deboning procedure requires very high skill and experience of meat processing work and an acquisition of this kind of skill takes many years of time, too.

III. HAMDAS Semi-automated Fresh Pork Ham Deboning System

1 Abstract of "HAMDAS"

Deboning work using HAMDAS device consists of the following two processes.

① Manual preparation process:

Removal of tail bone and hip bone and marking cut for automated deboning process using six (6) workers.

② Fully-automated deboning process:

Removal of leg bone, hind shank bone and kneecap using suspension method.

As shown in Figs. 2 and 3, the prototype HAMDAS system integrates manual preparation and automated deboning processes. The system is composed of 17 work stations in total, with the manual preparation work carried out at the front of the machine and the fully-automated deboning work carried out at the rear, the fresh hams passing from one work station to the next.

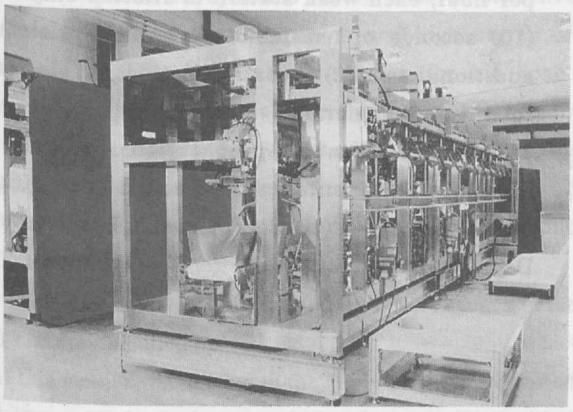

Fig.2. Picture of HAMDAS

Basic Specifications of HAMDAS:

Deboning speed	: 300 hams/hr
Electric supply	: AC 200V, 3Ph., 50/60Hz, 12kVA
Air supply	: 220 l/min (6kgf)
Raw material	: Bone-in fresh pork ham (right leg)
Required workers	: Seven (7) workers, including one (1) for loading raw material
Dimensions	: 8,000mm long x 1,800mm wide x 2,300mm high

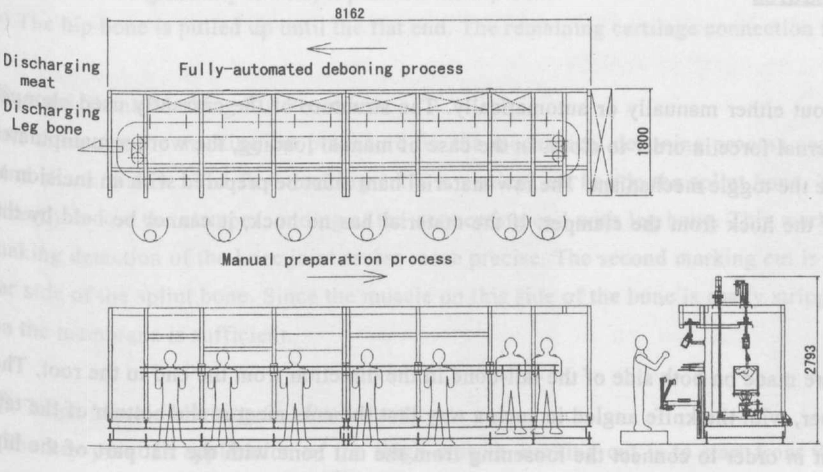

Fig.3. Views of HAMDAS

Key Features

: Reduced individual workload compared with conventional method due to segmented manual deboning procedures.

: No knife cut marks remain on products because actual deboning is accomplished by stripping off muscle.

: Better hygiene as deboning work is carried out on suspension method

2. Manual Preparation Process

Having confirmed product quality, yield rate, etc. of a combination of manual preparation and fully-automated deboning making use of the established procedures used in the conventional manual process, we created a new manual preparation process composed of seven (7) work stations. Fig. 4 shows a scene of the actual manual preparation process incorporated in the HAMDAS system.

The manual preparation process is composed primarily of the following two procedures:

Removal of the hip bone together with the tail bone, and incising of a marking cut for the automated deboning phase of operation.

Since removal of the hip bone and tail bone is too complicated to be carried out mechanically, it must be considered manual-intensive work. Nevertheless, we have developed an auxiliary device which facilitates this procedure and reduce workload. The marking cut procedure was incorporated in the manual preparation process as a means of stabilizing the results of the mechanical deboning procedure.

Fig.4. Manual Preparation Process

The conventional manual deboning method involves labor-intensive work on a boning table.

The HAMDAS system deboning procedure utilizes a clamper to suspend the raw material, which is processed using a suspension method. To improve work efficiency, we adopted an arrangement which supports the back of the raw material at an angle of 30 degrees using two (2) guide bars. This allows right-handed workers to use their left hands during the work as the weight of the raw material holds it steady against the guide bars. In addition, this method eliminates the fatigue associated with working in an unnatural position at a deboning table as the worker can stand with his back straight.

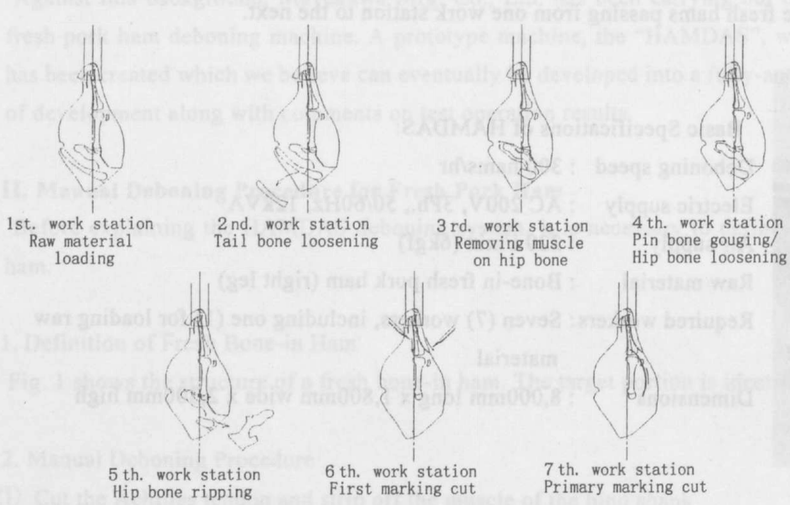

Fig.5. Manual Deboning Procedures

With deboning speed determined to be 300 legs per hour, each work station is allotted only ten (10) seconds of available work time, with an additional two (2) seconds allotted for station-to-station transfer.

The entire manual preparation process is therefore segmented into seven simplified procedures of ten (10) seconds each. Fig. 5 Manual Deboning Procedures.

Details of each process are as follows:

① Raw Material Clamper Loading Procedure

Raw material loading onto the clamper is carried out either manually or automatically. The structure of the currently used clamper incorporates a toggle mechanism which requires external force in order to close. In the case of manual loading, the worker manipulates a foot-switch to actuate a pneumatic cylinder to close the toggle mechanism. The raw material ham must be prepared with an incision at the Achilles tendon in order to allow suspension of the hock from the clamper. If the material has no hock, it cannot be held by the clamper.

② Tail Bone Loosening Procedure

In the loosening procedure, the first shallow cuts are made on both side of the tail-bone in the direction from the end to the root. The second cuts are made in the same manner only deeper, with the knife angled in such a way that the cuts meet at the bottom of the tail bone. The second loosening procedure is carried out in order to connect the loosening from the tail bone with the flat part of the hip bone. Although the above procedure essentially follows the conventional manual loosening procedure, it results in a different workability between right and left legs because the suspension method is employed.

③ Procedure for Removing Muscle Remaining on Hip Bone

Muscle remaining on the hip bone interferes with hip bone removal and must be taken off beforehand. The loosening procedure is extended from the pin bone to the cavity of the hip bone, then to the flat part of the hip bone, ending up at the tail bone. The muscle on the hip bone can then be stripped off the loosening point toward the tail bone and a peripheral loosening done onto the hip bone. The surface of the hip bone is now completely exposed and the muscle on the hip bone hangs down between the hip bone and the tail bone. The above procedure also results in a different workability between right and left legs as in the case of ② above. The procedure is the same as the conventional one used in Japan.

④ Gouging Procedure for Pin Bone and Loosening Procedure for Cavity Portion of Hip Bone

The ripping procedure for the hip bone is carried out by first gouging up the pin bone and cutting off at the flat part of the hip bone.

This makes it much easier to pull up the hip bone with the proper loosening procedure applied on the back of the pin bone and the cavity portion of the hip bone. A sectional view of the pin bone reveals it to have a somewhat triangular shape, with a high spot on the back, so cutting the tendon from the back facilitates pulling up the pin bone. A loosening of the cavity portion of the hip bone is next carried out, leaving the muscle in the cavity connected to the thigh muscle. The surface of the hip bone is scored with the knife from the back of the pin bone to the hip bone joint.

⑤ Hip Bone Ripping Procedure

Fig. 6 gives a side view of the auxiliary device with raw material suspended from a clamper. The auxiliary device is used to remove the hip bone from the raw material. This device is composed of a vertically movable pneumatic cylinder, a pulling pneumatic cylinder, a hook and three (3) foot-operated switches for controlling the movements of the two (2) pneumatic cylinders and the hook. In the conventional ripping procedure for the hip bone, considerable strength and high degree of skill and workmanship are required. In order to effectively remove the hip bone manually, the worker must forcefully pull it off with his fingers in the cavity while firmly holding the raw material down on the boning table. With the HAMDAS system, the worker manipulates a knife together with the auxiliary device.

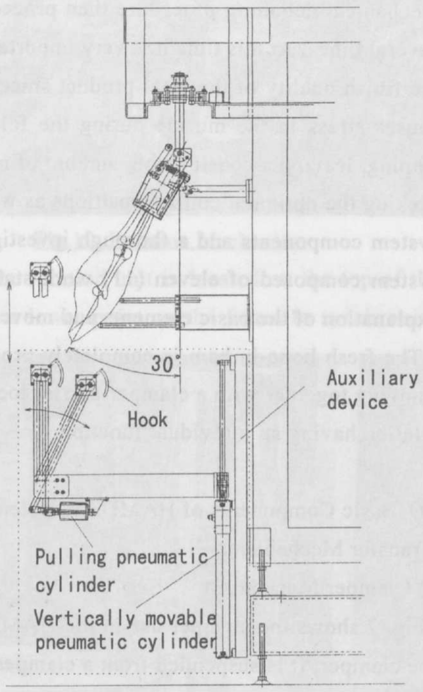

Fig.6. Side View of Auxiliary Device

Procedure performed with the auxiliary device are as follows:

i) The arm with the hook is tilted forward.

ii) The entire device is lowered and the hook engaged in the cavity of the hip bone.

iii) The arm is pulled up.

At this moment the tendon in the hip bone joint is exposed.

iv) The entire device is lowered after the tendon in the hip bone joint is cut.

As the device gradually lowers, it pulls on the hip bone.

v) The hip bone is pulled up until the flat end. The remaining cartilage connection is cut with a knife to free the bone completely.

⑥ Hind Shank Marking Cut Procedure

At this point the marking cut procedure for the mechanical deboning process commences. Two (2) marking cuts are required on the hind shank muscle. The first marking cut is a vertical cut beside the splint bone. This cut proceeds along the splint bone from a point directly below the clamper, ending at the connecting end with leg bone. This marking cut allows for a better muscle ripping result by making detection of the knee joint recess more precise. The second marking cut is a vertical cut beside the tibia bone. It is made at the far side of the splint bone. Since the muscle on this side of the bone is easily stripped off by the meat separator, a shallow marking cut on the membrane is sufficient.

⑦ Thigh Muscle Marking Cut Procedure

The key point in application of the thigh muscle marking cut is to start from the end of the leg bone after the hip bone has been removed, the cut proceeding the marking cut on the hind shank muscle. This cut roughly divides the raw material into a right portion and a left portion, however, no marking cut is visible from the surface of muscle, so the worker's empirical experience in manual leg deboning work becomes a factor in maximizing the yield rate. The marking cut is almost the same as that in conventional manual deboning, that is, cutting along the membrane between the inside ham and the knuckle, then exposing the leg bone.

The above explanations outline all aspects of the manual preparation process.

Of the seven procedures, ⑥ and ⑦ are most important in achieving the highest quality of muscle as well as the greatest yield rate. While procedures other than ⑥ and ⑦ relate to removal of the hip bone, ⑥ and ⑦ are required preparation for the mechanical deboning process. In procedure ⑥, the first marking cut is more important than the next. If this procedure is poorly implemented and detection of the knee joint fails, built-in microprocessors at the following work stations cannot control positioning of the round cutter blades, resulting in total failure of the mechanical deboning process. Since a large portion of the leg bone surface is covered with an easily detachable membrane, muscle ripping is accomplished rather easily, however, the sinews extending perpendicularly from the end of the log bone may interfere with muscle ripping. For this reason, the manual marking cut on the leg bone outlined in procedure ⑦ which cuts the sinews beforehand contributes to better result in HAMDAS mechanical deboning process.

3. Fully-automated Deboning Process

The fully-automated deboning process requires raw material to be suspended by the hock from a clamper. Peripheral cutting by a round cutter at right angles toward the hind shank bone is first carried out at a position just below the hock and a meat separator having a pair of plates similar in shape to the hind shank bone pinches the hind shank bone at the peripheral cutting position. From this spot the raw material is lifted upward against the resistance of the meat pinching separator, stripping the hind shank muscle away. The mechanical deboning procedure then proceeds to the following work stations, alternately repeating the cutting and ripping procedure several times. At this time it is very important point to keep the number of cutting procedures to a minimum. The number of cuts affects the finish quality of the final product since each cut leaves cut marks on the product. If cutting is not performed at the right place, it causes stress in the muscle during the following ripping process and results in roughly ripped surfaces and/or insufficient muscle ripping, leaving a considerable amount of meat on the bone. During development of the HAMDAS system we spend considerable time seeking the optimum cutting positions as well as the smallest number of cutting procedures. Though intensive study of the most stable system components and a thorough investigation of fully-automated deboning, we finally concluded that a fully-automated deboning system composed of eleven (11) work stations was most suitable. Before presenting detailed explanations of each work station, an explanation of the basic elements and movements composing the fully-automated deboning equipment is called for.

The fresh bone-in ham is completely processed into boneless muscle and waste bone while suspended by the hock from a clamper moving together with a clamper-carrier located at the top of the equipment from work station to work station in succession, each work station having an individual function.

① Basic Components of HAMDAS System

Transfer Mechanisms

i) Clamper Mechanism

Fig. 7 shows the clamper use in the HAMDAS system. This incorporates a toggle mechanism for affixing a fresh ham by the hock to the clamper. It is suspended from a clamper-carrier and equipped with no source of driving power. The hook of the clamper is actuated by external force. It is fitted with a spring-loaded, self-adjusting mechanism to ensure proper fixation of the raw material in the clamper since each individual hind shank bone has an individual deviation in diameter. The clamper itself is suspended from and affixed to the clamper-carrier. In addition, the clamper is fitted with a 30 degree, 0 degree tilting mechanism to facilitate manual work at the 30 degree tilt angle and fully-automated work in the 0 degree, or vertical position.

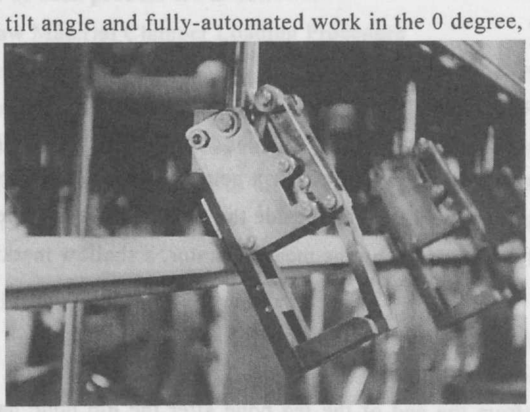

Fig.7. Clamper

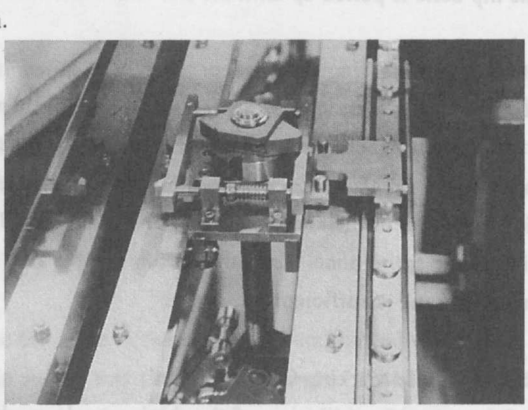

Fig.8. Clamper-carrier

ii) Clamper-carrier and Transfer Mechanism

Fig. 8 shows the clamper-carrier. HAMDAS system is equipped with twenty-six (26) clamper-carriers for moving the raw material, driven by means of a chain connection on a limited rail passage with rollers. The clamper-carriers move simultaneously between work stations at two (2) seconds intervals, remaining at each work station for ten (10) seconds before proceeding to the next work station. At each work station are 360 degree rotation and/or clamper lifting mechanism. Each clamper-carrier is fitted with a positioning mechanism to affix itself and a bearing allowing rotation and lifting of the clamper. In addition each clamper-carrier is equipped with an anti-rotation mechanism to prevent rotation of the clamper during the work station-to-work station transfer phase.

Work station devoted to sinew cutting and muscle ripping

iii) Round Cutter Mechanism and Rotation Mechanism

Fig. 9 shows the round cutter unit and Fig. 10 shows the rotation mechanism. The round cutter has been selected in consideration of long-term sharpness and is driven by a motor equipped with a gear box. In addition, this cutter unit is fitted with a mechanism allowing back and forth movement in order to prevent it from interfering with the transfer of raw material between work stations. It is tensioned by pressure a pneumatic cylinder so as to properly press the round cutter against the object bone. It is necessary to move the cutter unit around the hock of the raw material in order to make a peripheral cut, however, this is technically very difficult. We therefore adopted a method whereby the raw material itself is rotated together with the clamper and the meat separator unit. The rotation unit is located on the top of the frame. It rotates the clamper while transmitting rotation through interconnecting shafts to a lower point on the frame to synchronize rotation of the meat separator unit.

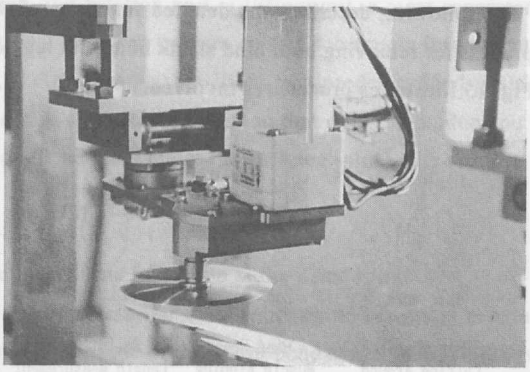

Fig.9. Round Cutter Unit

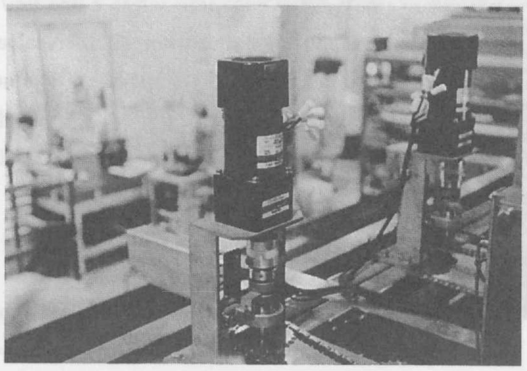

Fig.10. Rotation Mechanism

iv) Meat Separator Mechanism and Lifting Mechanism

Fig. 11 shows the meat separator unit and Fig. 12 shows the lifting unit. The meat separator is composed of two (2) meat separation plate, a plate actuating mechanism and a rotation mechanism. Since a key function of the two (2) meat separation plates is to rip off muscle around the relevant bone, each plate has a template with a section view of the relevant bone at the particular work station. Specific plates are equipped with additional movable scraper plates in order to accommodate variations in the sectional views at different positions on the relevant bone.

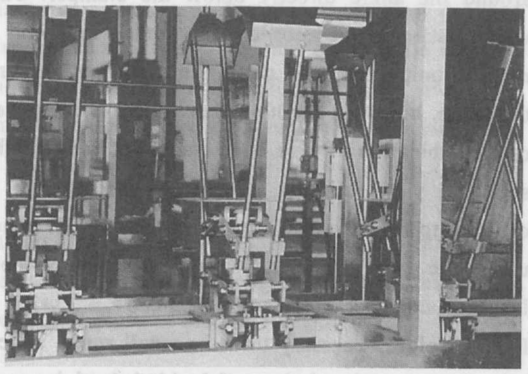

Fig.11.Meat Separator Unit

The actuation mechanism for the meat separator unit is a mechanism for pinching the relevant bone with the relevant plates. It controls pinch pressure so as to assure safe ripping of the muscle without damaging the relevant bone. Actuation of the two (2) meat separation plates is accomplished by means of controlled air pressure. A lifting mechanism of the clamper is used to rip off a muscle from a relevant bone. A ripping procedure of muscle is completed to lift up the clamper while pinching the bone with the template plates of meat separator. The lifting mechanism must be flexibly controlled since the lifting height of the clamper varies from work station to work station and/or depending upon individual deviations in the raw material. The HAMDAS system is therefore equipped with servo-motors as the driving force and ball screws.

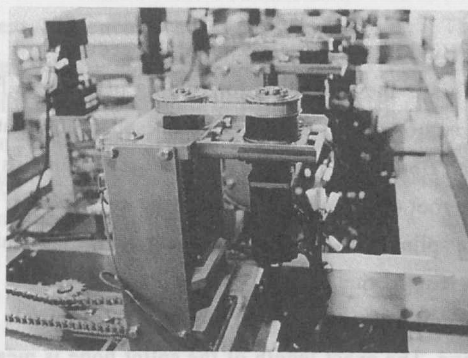

Fig.12. Lifting Unit

Work Station Governing Measurement

v) Measuring Mechanism

Fig. 13 shows the splint bone measuring unit and Fig. 14 shows the leg bone measuring unit. Each bone-in ham exhibits individual variations in bone length. At each work station the optimum cutting position as well as the optimum lifting height is empirically obtained, however, individual variations in bone length cannot be determined. Since it is empirically known that the individual deviation of the knee joint is smaller than the deviation of the leg bone and the hind shank bone, automated deboning becomes practical on condition that the lengths of the leg bone and hind shank bone can be measured. Instead of measuring the length of the leg bone, a device measures the length of the splint bone, taking advantage of its specific shape. The measuring device is composed of two (2) plates which are pressed against the splint bone, an encoder to detect phase deviation,and a pneumatic cylinder to actuate the two (2) plates. The leg bone length measuring device is composed of a pneumatic cylinder to lift the clamper, an encoder set, a rack and a pinion gears to measure the lifting length.

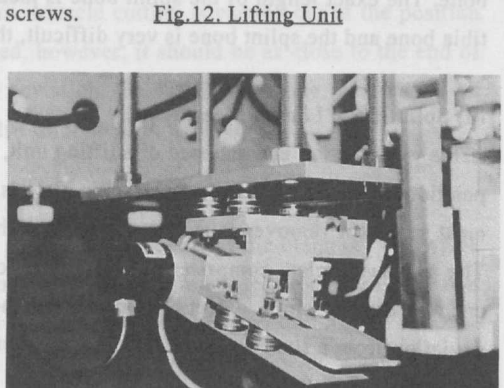

Fig.13. Splint Bone Measuring Unit

HAMDAS is composed of the above-outlined basic elements.

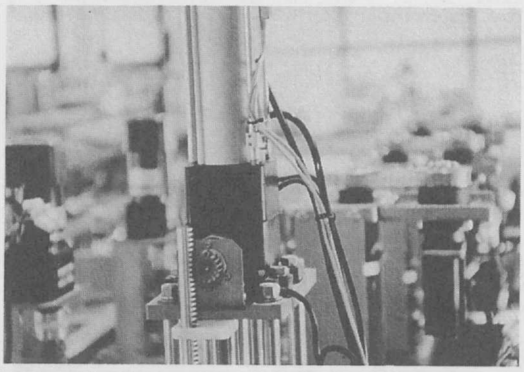

Fig.14. Leg Bone Measuring Unit

② Detailed of Fully-automated Deboning Process Procedures

The following describes the detailed functions of the fully-automated deboning process for removing both hind shank bone and leg bone.

Fig. 15 illustrates procedures involved.

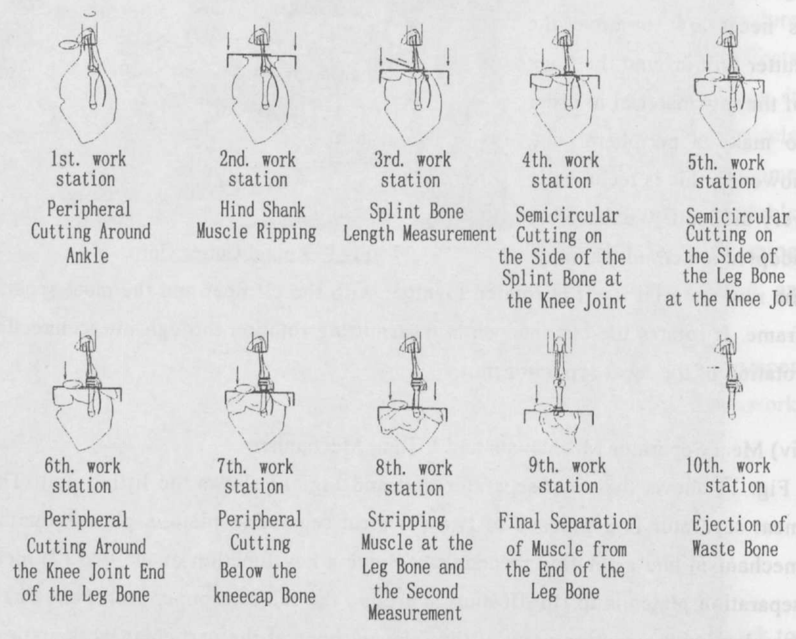

Fig.15. Fully-automated Deboning Process

i) Peripheral Cutting Around Ankle

A round cutter is used to make a peripheral cut around the ankle directly below the clamper. This work station is composed of a cutter unit and a rotation unit. Peripheral cutting is carried out around the ankle, however, the hind shank bone is composed of a combination of tibia bone and splint bone, so the sectional view is quite complex. Especially, it is difficult to rip off muscle between the two (2) bones using the two (2) meat separation plates without leaving a considerable quantity of meat. It is therefore necessary to use a small round cutter which is small in diameter to ensure appropriate peripheral cutting around the complicated sectional plane of the hind shank bone.

ii) Hind Shank Muscle Ripping Procedure

This is the procedure for ripping off muscle from the hind shank bone. The work station is composed of a lifting unit and a meat separator unit. The two (2) meat separation plates pinch the hind shank bone at the point where peripheral cutting is carried out and then rip off the muscle. The meat separator rips off muscle to the empirically determined lifting high, which ends up to be just before the root of the splint bone near the knee joint. If the muscle is ripped off beyond the root of splint bone, the meat separator may damage the splint bone and the measuring device may fail to detect the end of this bone. Since each hind shank bone has an individual deviation in length, the clamper cannot be lifted to the exactly required height without measuring the length of the splint bone. The meat separator therefore stops ripping off the muscle at the empirically determined lifting height, which never exceeds the root of the splint bone. The exact length of the splint bone is measured at the following work station. As mechanical removal of all muscle between the tibia bone and the splint bone is very difficult, there remains approximately 15 grams of muscle attached between these bones.

iii) Splint Bone Length Measurement

This work station is composed of a lifting unit, a measuring unit and a meat separator unit. The meat separator is first positioned at the position of the first cut and a measuring plate is pushed toward the surface of the splint bone. A spring-tensioned scraping plate on the meat separator removes muscle remaining on the surface of the splint bone while the measuring plate detects the shape of this bone. The measuring plate comprises two (2) plates, one of which is a fixed plate and the other of which is movable, being connected to an encoder device which detects the recess on the bone surface based on the deviation of the two (2) plates. When a predetermined deviation from a fixed value is detected, the distance which the raw material is lifted is registered as the particular measurement of the particular raw material.

iv) Semicircular Cutting on the Side of the Splint Bone at the Knee Joint

This work station is composed of a rotation unit, a lifting unit, a meat separator unit and a cutter unit. The cutting unit incorporates two round cutters in combination, which can prevent cutting too deeply into the muscle. After the meat separator pinches the hind shank bone at the first cut position, the raw material is lifted to a predetermined position and the extended sinews around the bone are cut away. This cutting is carried out in a semicircular arc so that only the tendons on the side of the joint are cut away. Since no cutting is performed on the kneecap bone, it remains intact on the knee joint. This reduces the work required in the follow-up manual trimming process.

v) Semicircular Cutting on the Side of the Leg Bone at the Knee Joint

This work station is composed of a rotation unit, a lifting unit, a meat separator unit and a cutter unit. The cutting procedure is essentially the same as that used on the side of the splint bone at the knee joint, however, the cutting device incorporates only one round cutter blade.

vi) Peripheral Cutting Around the Knee Joint End of the Leg Bone

This work station is composed of a rotation unit, a lifting unit, a meat separator unit and a cutter unit. Peripheral cutting at the knee joint end of the hind shank bone is important in exposing the root of the knee joint for the next work station. This part has a highly constricted bone from the diameter of the knee joint, causing poor muscle stripping results much like those for the meat between the tibia bone and the splint bone. Correct cutting allows for easy muscle stripping at the next work station and achieves a better yield rate.

vii) Peripheral Cutting Below the Kneecap Bone

This work station is composed of a rotation unit, a lifting unit, a meat separator unit and a cutter unit. Peripheral cutting is carried out around the leg bone to facilitate muscle stripping together with the membrane at the next work station. If peripheral cutting fails to cut the muscle together with the membrane around the bone, the yield rate as well as the quality grade of the muscle is reduced.

viii) Stripping Muscle at the Leg Bone and Second Measurement

This work station is composed of a lifting unit by means of a pneumatic cylinder, a measuring encoder and a meat separator unit. The result of the first measurement is no long reliable for determining the optimum cutting position on the leg bone so it is necessary to carry out additional measurement to establish the basic starting position. The purpose of this work station is to strip off the leg muscle, however, a fixed lifting height cannot be applied because of the significant deviation in leg bone length. Taking advantage of the muscle stripping resistance during the lifting process, the actuation of the pneumatic cylinder is stopped at a predetermined resistance value. The measurement calculates the distance between the halted position and the bone head of the leg bone and creates a new basic value for determining the cutting position at the end of the leg bone.

ix) Final Separation of Muscle from the End of Leg Bone

This work station is composed of a lifting unit, a meat separator unit and a cutter unit. Muscle cutting is carried out at the position obtained by the second measurement. The position of the cutter is empirically calculated, however, it should be as close to the end of the leg bone as possible in order to ensure the highest yield rate. Due to the individual deviation, the cutter may come in contact with the bone and fail to cut off the muscle. In this case, additional cutting is applied with a lift of predetermined height.

x) Ejection of Waste Bone

In order to eject the waste bone from the clamper the hook is unlocked and a pusher pushes the bone out of the clamper. The waste bone then drops onto a discharge conveyor. Here, the leg bone, hind shank bone and kneecap bone are discharged from the HAMDAS system. Since no joint cutting is applied to the knee joint, all waste bones are connected each other as a monolithic form.

IV. Production Plant Test Operation

The prototype HAMDAS machine was test operated at a meat processing plant in Japan in order to identify any mechanical and operational problems before introduction to the market on a commercial basis.

Various information/data such as weights of raw material, measurement of the splint bone and the leg bone, yield rates, etc. were collected and analyzed.

1. Efficiency of Manual Deboning Work

The HAMDAS system requires manual preparation work in order to function properly. The system developed by us can be adopted by commercial meat processing plants with good results. The current manual preparation work is divided into six (6) procedures, excluding the loading work. The greatest difference in workability depends on the deboning procedures used for right legs and left legs.

Between right legs and left legs, the most significant difference in workability is the procedure for loosening out to the back of the pin bone. The loosening procedure for the back of pin bone starts from top and proceeds down to the tip of the pin bone. Judging from the knife cutting angle for a left leg, a right-handed worker has better work position because the pin bone of the hip bone is positioned on the right side, viewed from the relevant worker's side. However, the position of pin bone is inconvenient for a left-handed worker. On the other hand, in case of a right leg, a right-handed worker has the identical handicap. When carrying out deboning work on a boning table, the leg can be positioned at the convenience of the worker so no problem of workability exists.

The above was found to be problematic during HAMDAS test operations.

A remarkable reduction of work load was accomplished at the removal procedure of the hip-bone, and a combined procedure with the suspension method and the auxiliary device for a removal of the hip-bone was found very effective. The suspension method of raw material does not cause any difficulties to carry out a loosening procedure.

Intermittent transfer to the next work station may cause some stress on manual workers. A cycling time of twelve (12) seconds consisting of two (2) second transfer time and a ten (10) second standstill at the work station means that each manual preparation worker must complete his assigned work within ten (10) seconds. As a result, the manual processing workers used during testing could not limit actual work time to within ten (10) seconds. We conclude that the intermittent transfer with a ten (10) second standstill should overwritten by continuous transfer at a fixed speed.

Concerning the required number of manual preparation workers, the prototype HAMDAS unit requires seven staff, including one individual responsible for loading the raw material into the system. This number of workers are the minimum required to operate the prototype HAMDAS system. In comparison, with a full manual deboning system, the number of workers required is flexible, depending on the workload, so in this sense it could be considered the more effective system. In application where a production level of less than 300 legs/hr is intended, the required number of manual preparation workers for the prototype HAMDAS system must be reduced for reasons of economy. One idea for resolving this problem is to do away with segmentation work and apply a conventional manual approach under which each individual worker completes deboning of the hip bone himself.

As an interim conclusion, we assume the following two processes;

The first possible process is for raw material to be fixed in a clamper and transferred horizontally at a fixed speed up to the fourth work station. The raw material is then further transferred at a tilt angle of 30 degrees from the fifth to the seventh work stations, all the while being processed. In the second scenario, all necessary preparation work is carried out on the raw material beforehand and the raw material is then suspended from the clamper and undergoes the fully-automated deboning process provided by HAMDAS.

Implementation of either of the suggested forms of processing offers advantages, depending upon various conditions such as production volume, available floor space at the processing plant, and so on. Our final conclusion is that the manual preparation process and the fully-automated deboning process should be completely isolated from each other.

2. Yield Rate and Product Quality

Fig. 16 shows the appearance of deboned fresh ham and Fig. 17 shows the appearance of waste bone. The yield rate referred to herein is determine dividing the weight of the fresh bone-in ham by the weight of the fresh deboned ham.

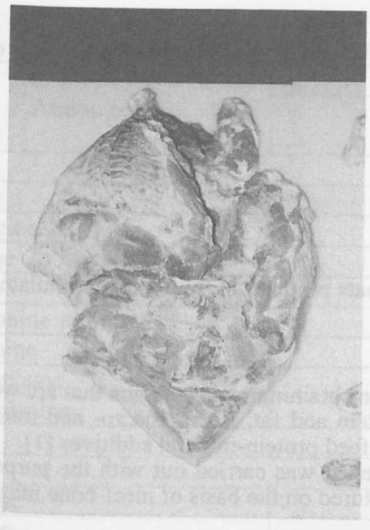

Fig.16. Appearance of Deboned Fresh Ham

Fig.17. Appearance of Waste Bone

Average yield rates during test operation were as follows:

Skin-off fresh ham	: Yield rate of **86.64%**
Skin-on fresh ham	: Yield rate of **88.23%**

With regard to evaluation of product quality, the results is dependent in part on the results of the manual preparation process described earlier. In general, the yield rate and the quality show no significant difference from that resulting from manual deboning by a skilled worker with the exception of the muscle remaining between the tibia bone and the splint bone. Further labor saving remains to be accomplished, e.g. workers are required to practice complicated and deeper marking cuts against the raw material in order to increase the yield rate.

V. Summary

The prototype HAMDAS system comprises a fully-automated deboning process of leg bone as well as hind shank bone and a semi-automated deboning process of hip bone as well as tail bone. Both processes have been assembled into a common frame together with various devices practically required to accomplish the deboning work and the device subjected to test operation at a processing plant in Japan.

During field testing valuable data on boning work as well as the opinions and comments of workers involved in the testing were recorded. A wealth of information on deboning skills and workmanship available from skilled workers remains to be recorded and we believe this information will improve the capability of the prototype HAMDAS system and the development of a fully-automated deboning robot. The quality of the HAMDAS system deboned product has received high praise for its quality from various people involved in the meat industry and we are convinced that practical introduction of the system will be received with a positive response. Numerous aspects of the system, e.g. the complicated manual preparation procedure, further reduction in workload, sanitation, cleaning method, easier manipulation of operation, etc. remain to be improved.

It is our sincere wish that we are able to contribute to further development of the meat processing industry by developing better robotics technology based on the information acquired during the development and field testing of the HAMDAS system in order to significantly reduce labor-intensive work.