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Automated ovine shoulder breakup – follow up

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Abstract

A machine to break up the shoulder primal of ovine carcasses by performing neck, brisket and shank, and splitting for square cut shoulder has been developed. A commercial solution is now available avoiding the need to use band-saws. The project has considered the variability in the shoulder primal piece from carcasses in a wide weight range and accommodates for the variability. Trials using a prototype machine at a nominated plant have demonstrated capability that compares with and is more economically attractive than using band-saws. Calculations show payback of better than 24 months based on bone-dust reduction.

This report marks the conclusion of the research, whilst pointing to development possibilities that would enhance performance as the machine becomes more widely used in the commercial environment.

Executive summary

The ovine shoulder machine for breakup of lamb forequarters or shoulder primal pieces has been considered by the project to the point of a final production prototype machine, replacing band-saws.

The main requirement of the machine is to deliver the process that produces the square cut shoulder primal as in Figure 1.

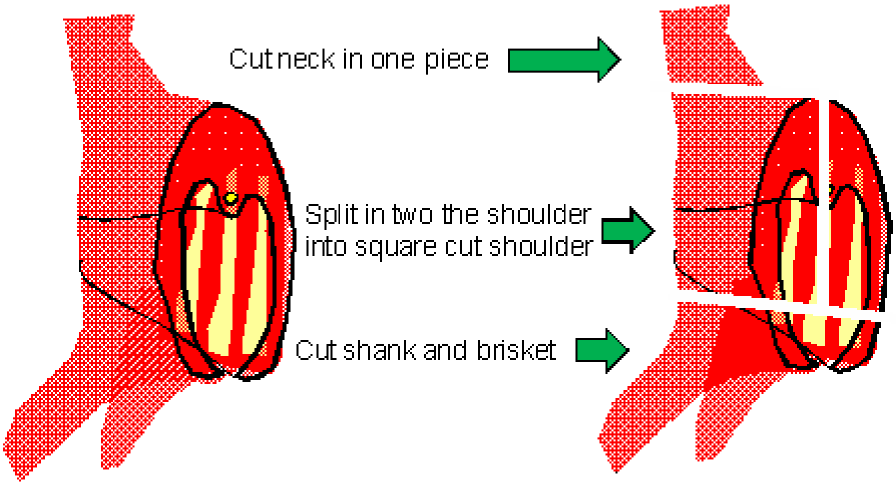


Figure 1. Cuts performed by the new ATTEC Shoulder machine from AMPC-MLA project executed by BMC with ATTEC Denmark.

The project has reached the completion of its development stages as follows:

1. Review of shoulder primal variability has been conducted
2. Tests were performed with Mechanisms to reach stable design for cutting
3. Concept design have been proposed and documented for industry consultation
4. Key modules have been implemented for testing and improvement of cutting
5. A new machine has been designed and constructed for trials
6. Tests have been conducted before shipment to Australia
7. On site, testing and improvements have been conducted
8. Modifications and improvements have been done based on production tests
9. Final testing has been done to show performance and update of benefits with benchmark comparison to the current manual band-saw process.

Similar to the ATTEC Rack Barrel machine, the shoulder machine has an indexing carrier conveyor, with an in-feed section for placement of the shoulder, which transfers the primal piece through the machine. A series of 3 cutting stages separate the shank and the brisket and then the neck is cut before the third stage that splits the shoulder in two. The project has concluded its trials with the prototype machine at WAMMCO in Western Australia, where the development machine has undergone testing to benchmark performance. The operating speed of the machine is 300 shoulders per hour.

Comparison with band-saw cutting reveals savings from the machine at over A$140,000 per year based on bone dust savings alone. An important benefit is that the machine distances the operator from cutting saws or blades, greatly improving OHS. Use of knife blades also increase the quality of the meat cut surfaces, whilst eliminating the need to scrape the meat to remove bone dust.

To operate the machine, an operator must manual place and locate a whole shoulder primal on an in-feed carrier conveyor and pressing a button for the carrier to automatically to indexes forward to make the cuts before loading another primal. Operating the machine is simple.

The cutting takes place as the shoulder primal travels through the machine. The shank and brisket are cut first followed by the neck and finally the splitting to produce the square cut shoulder as an end product from the machine. Once a carrier is indexed forward a new carrier presents itself for manual loading of a next shoulder primal piece. See Figure 2 top right photo. The resulting cuts (Figure 2, top left) and the square cuts from several shoulders are also shown.

Figure 2. Shoulder machine and resulting cuts during trials on site.

The machine is now available on a commercial basis, subject to modifications to make it more user friendly and robust as a production machine.

The savings from the machine suggest a fast rate of return on investment, based on savings from bone dust reduction alone. Benefits in OHS and improvements in cut quality have not been included in the calculations of Figure 3, which also illustrates the way in which the measurements were taken for the estimation presented.

The shoulder machine can be an important asset for many processors in Australia. ATTEC Australia will channel the supply and the first promotion will be at FoodPro 2014.

Shoulder Machine Benefits Estimation — scale error ±10g

Bone dust against 1 mm of band-saw thickness

Lamb	mm Thick	item	grams weight	grams 1mm wgt	multiple per shoulder	grams 1mm wgt
12-16 Kg	10	neck	80	8	1	8
	10	shank-brisket	130	13	2	26
	10	split	270	27	1	27
16-20 kg	10	neck	40	4	1	4
	10	shank-brisket	110	11	2	22
	10	split	230	23	1	23
			Total	86		110
				Number of shoulders measures		2
				Loss per lamb		55
				Round down		50
				A$ Price per Kg		5.00
				A$ Gain per lamb		0.25
				Machine rate	per hr	300
					A$ per hr	75
					hrs/wk	40
					AS/wk	3000
					wks/yr	48
				A$ saving per year		**144,000**

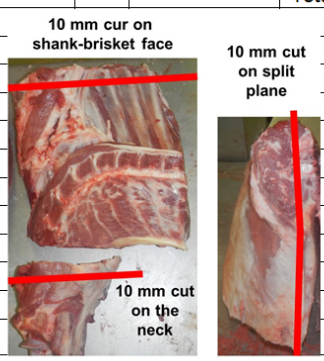


Figure 3. Calculation of benefits against bone dust only

Contents

1. Background

Several small stock processors in Australia involved with BMC expressed a requirement for a simple approach to shoulder break up that reduces bone dust and reduces and places distance between the operator and the band-saw removing the risks associated with performing the task manually. BMC considered the basics for such a machine using the ATTEC design for similar machines. The main features of the machine were tested in test area in Denmark at ATTEC and the basic modules designed for testing in a two stage project. The first stage (A.TEC.0086) proved the capability can be reached using standalone modules. The second and final stage, under this project integrated the modules to a fully operational machine for testing in an Australian plant.

2. Project objectives

The main objective of this project has been to develop a machine that breaks up a lamb shoulder. This research and development have aimed:

a) To assess the variability in ovine shoulder primal pieces and consider the adaptation to the carrier shape for the new machine
b) To perform tests that define the cutting approach to achieve the square cut shoulder
c) To present a document for industry consultation outlining the concept design
d) To develop the machine modules to the point of testing off-line
e) To integrate the modules into a working machine for testing
f) To carry out testing in an Australian plant.
g) To improve the design of the machine as necessary to reach capability for commercial solution.
h) To reach a benchmarks of capability against current band-saw practice.

All the objectives have been met.

3. Methodology

The project has taken a two phase process to reach its target. The first phase dealt with objectives (a) to (d), reported previously under A.TEC.0086, where successful modules for the machine were designed and tested before the second phase, aiming for objectives (e) to (h). Note that the results of A.TEC.0086: Phase 1 are included in this report as relevant for completeness.

Understanding the variability has given rise to the design of a carrier that fixates the shoulder for cutting as it moves through the machine. Accommodating the variability has been the key to success for the machine, whilst giving flexibility to the processor to position the cutting lines.

The stages of the project have followed in stages minimising risk of development by designing modules that must be proven technically and in concept before proceeding to the next module. The carrier design has been the first module followed by the splitting and then the neck cutting module requiring sensing for adjustment of cut position using a laser measuring solution and finally the shank and brisket module. The systematic approach has resulted in the integrated machine solution as the prototype, which has been tested and provides the basis for a commercial solution.

The progression of the project is presented in the following subsections.

4. Results and discussion

4.1. Review of variability

The main reason for reviewing the shoulder primal variability as the first step in the project is to support the definition of the machine features that provide for the capability of breaking up the shoulder primal from an ovine carcass into sub-primal pieces.

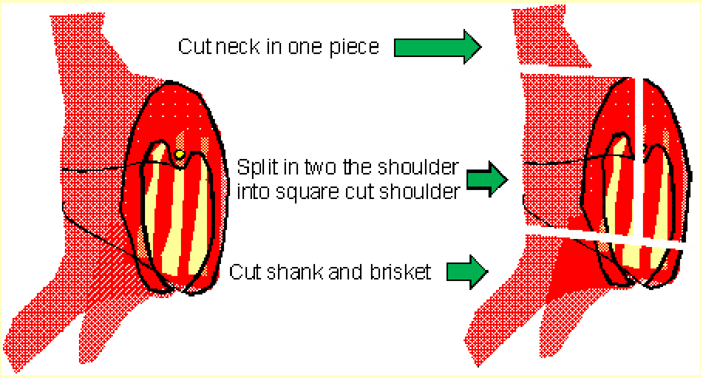


Figure 4.1. Shoulder machine cuts

The main cuts are shown in Figure 4.1. The cuts are separation of the neck in one piece, removal of shank and brisket and the splitting of the remaining piece into two square cut shoulder pieces.
The cuts are presently performed on a band-saw involving 3 band-saw actions.

The project has aimed to eliminate the operator contact with band-saws by defining and building a machine that performs the breakup of the shoulder.

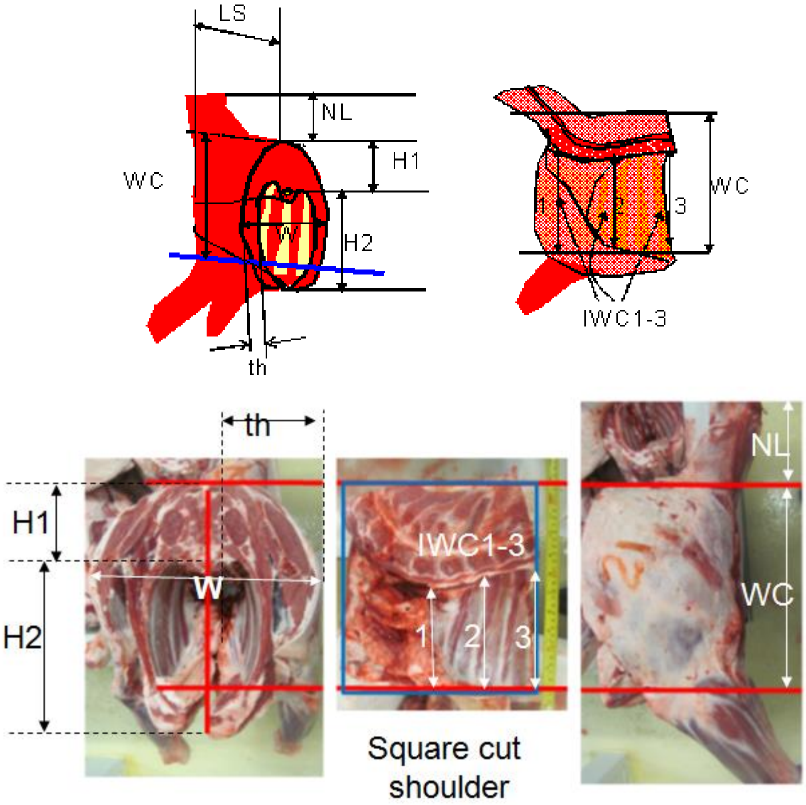
The measurements of key carcass features have provided the basic data for the specification of mechanisms and machine features including sensory functions to perform the cuts required, meeting the specification of the end product: the square cut shoulder, irrespective of the variability in the shoulder primal.

Measurements have been performed on available carcasses in the range 15Kg to 40Kg (see Figure 4.2).

Figure 4.3 presents the feature in the shoulder primal pieces considered relevant and significant to the specification of the intended break up machine in terms of variability that exists in the shoulder primal range to be accommodated.

Figure 4.2. Carcasses used in the measurements.

The measurements taken are shown in Table 1 against the dimensions in schematic drawing of the shoulder in Figure 4.3. IWC is measured from the lower edge of the internal spine at the narrowest point from the curvature on the neck to the shank/brisket cut (IWC1), at the edge of the shoulder cut face from the rack end to



Kg	Weight of whole carcass from which the measured shoulder originated
L	Length of whole carcass from which the measured shoulder originated. Measured from the hook position to the bottom of the neck with carcass hanging from the hook.
WC	Width of cut measured from the back of the shoulder to the position of the cut separating shank and brisket
NL	Neck Length
H1	Distance between the back and the centre of spinal cavity
H2	Distance between the centre of the spinal cavity and the tip of the brisket
W	Widest width of the shoulder
th	Thickness of the shoulder
IWC	Internal distance between the edge of the brisket and the position of cut as marked by WC. This is done in three positions 1, 2 and 3 to show the profile of the spine
LS	Length of shoulder measured from the rib cut position to the bottom of the neck

Figure 4.3. Measurements specification corresponding to features relevant to definition of shoulder machine

the shank/brisket cut (IWC3), and at the mid-point between two measurements again from the spine to the shank/brisket cut (IWC2).

Table 1 presents the measurements made on shoulders. The measurements are subject to a tolerance of 5 mm and are representative of Australian carcasses.

A.TEC.0097 Shoulder primal size variation								All in mm				
Item	Kg	L	WC	NL	H1	H2	W	th	IWC 1	IWC2	IWC3	LS
1	16.7	1010	200	100	65	220	210	25	95	105	115	180
2	16.7	1040	200	120	65	215	230	110	105	110	135	180
3	17.2	1100	215	140	65	220	200	95	120	130	140	180
4	17.2	1100	215	135	65	220	220	95	120	130	140	180
5	18.7	1110	215	130	70	220	220	105	120	125	130	180
6	18.4	1050	200	110	70	235	230	100	105	115	125	170
7	19.1	1110	210	130	75	230	230	105	105	115	125	185
8	19.7	1110	220	120	76	235	260	110	105	116	125	180
9	20.7	1070	210	120	75	230	230	110	105	115	125	180
10	20.8	1190	230	110	65	200	215	100	130	140	150	170
11	21.2	1110	220	110	75	225	250	110	115	125	125	135
12	21.7	1120	220	100	65	230	220	95	105	120	135	160
13	22.4	1165	230	120	80	240	220	95	135	140	150	190
14	22.5	1180	230	120	80	235	225	100	125	135	150	210
15	22.8	1150	230	110	70	230	230	90	130	135	145	190
16	23.6	1130	210	110	80	230	260	95	115	125	135	190
17	24.2	1120	230	110	85	245	230	110	115	125	135	190
18	24.9	1110	210	110	75	230	270	105	110	120	130	180
19	25.9	1130	220	120	80	230	240	100	110	115	125	200
20	26.1	1110	220	100	80	225	240	100	110	115	125	200
21	26.6	1170	240	140	80	225	290	100	115	120	130	190
22	26.9	1180	235	110	80	245	270	100	130	135	140	190
23	27.3	1170	220	120	85	235	280	90	125	130	140	210
24	27.7	1150	240	110	85	240	250	90	125	135	140	190
25	27.3	1220	230	140	95	235	285	90	110	120	130	200
26	25.1	1200	230	120	90	240	285	100	110	120	130	200
27	28.6	1130	230	130	80	225	280	100	115	125	135	190
28	29.9	1140	230	120	95	225	240	110	130	130	135	200
29	30.2	1120	240	120	85	240	290	120	125	130	140	200
30	36.1	1240	240	115	90	230	270	120	130	140	150	230
31	36.8	1250	250	130	85	250	165	110	120	130	140	220

Table 1: Measurements presenting the variability in shoulder primal pieces from carcasses 15Kg - 40Kg in relation to features in Figure 3

The measurements show variability of the shoulder primal in overall dimensions and in specific feature positions important to the design features of the intended machine.

4.2. Testing with Mechanisms

The cuts are presently performed on a band-saw involving a minimum of 3 band saw actions.

The focus of the R&D has been the definition of approaches for handling and fixation of the shoulder primal piece and the cutting approach to achieve the same end result as on a band saw but by an automatic machine.

Measurements presented in Section 4.1 define the range of variability that needs to be accommodated by the machine.

The most critical aspect of the design will be the process by which simple loading can be done by 'unskilled' operator and the way in which the shoulder primal is to be held without movement or miss-orientation in a manner that provides a means for cutting.

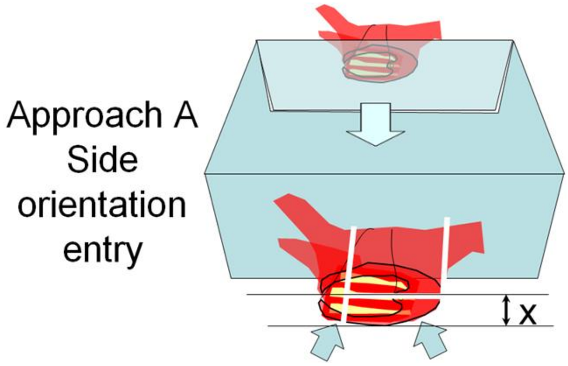
The different approaches are presented in Figure 4.4 and the trials with the shoulder orientations were carried out for the 3 approaches A, B and C with the main finding that approach B is the most appropriate.

Figure 5 presents the concept for a fixation mechanism that was developed over several attempts during testing.

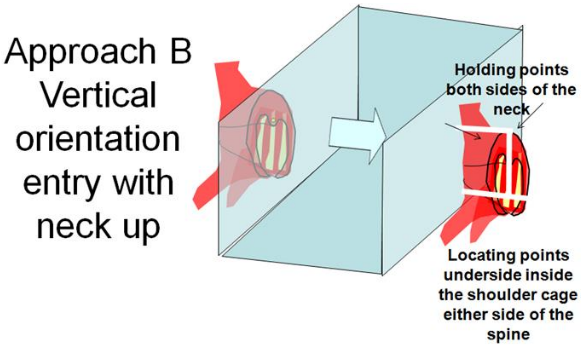
The main features of the fixation unit include:

a) Two shaped plates that locate on the inside of the shoulder primal, centring the shoulder whilst keeping the path for the split cut clear

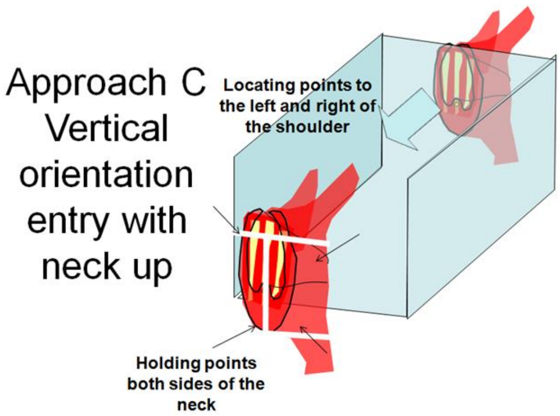
b) Shaped profile on the plates are such that they keep the back of the



A: Side orientation



B: Vertical orientation neck up



C: Vertical orientation neck down

Figure 4.4. Approach to in-feed and orientation

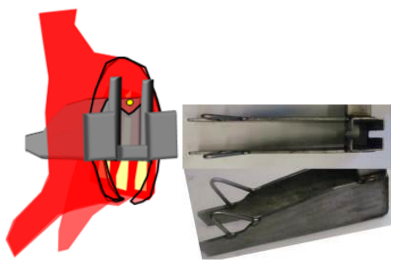


Figure 4.5. Fixation approach first concept

shoulder horizontal as shown in Figure 4.5.

c) Locating bars hold the shoulder in such manner that allows the neck and the brisket-shank cuts to be made above and below the mechanism.

Figure 4.6. Range of shoulders of different size and shape located on the fixture

The fixture mechanism does not obscure any features that may require sensing namely the position of the back of the neck and the brisket edge.

The fixture mechanism implemented after several iterations on a practical basis.

Figure 4.6 shows the shoulder primal of varying size located on the fixture.

Based on the features of this fixture design and implementation of the modules for the shoulder machine was to proceed as part of the main carrier assembly.

4.3. Design concept

The next step in the project was the implementation of the carrier modules with the three cutting modules that would perform the specific cuts on the shoulder separating out the square cut shoulder by removing the neck, the brisket and shank and splitting.

Figure 4.7 presented the design approach to the machine and based on the approach C, the specific cutting modules were fabricated for testing.

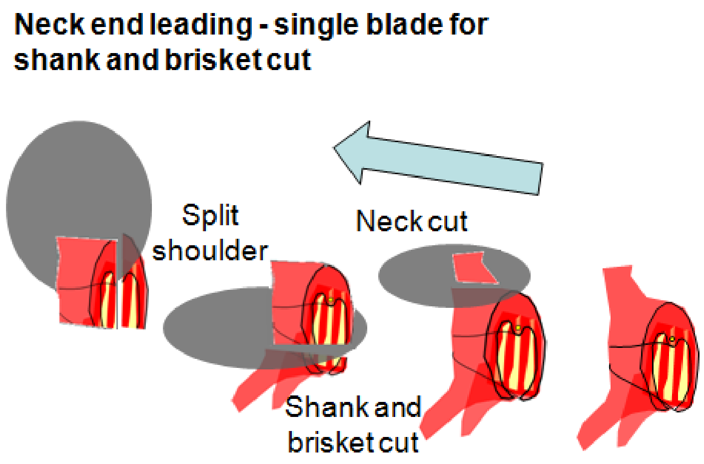
The trials were successful in reaching the desired solution and the prototype units have been tested.

The next step of the project is to reach a full assembly of the machine for trials in early 2013 in an Australian plant.

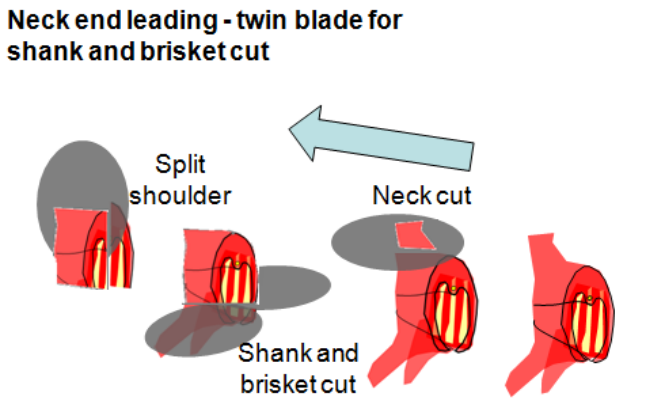
Figures 4.8 present the images of the various modules in final implementation with the overview of the design shown in Figure 4.9.

The machine is operated as follows:

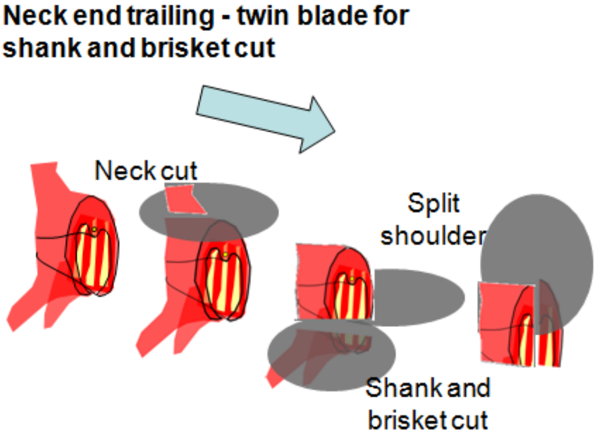
- Load shoulder, neck trailing and down,
- Index carrier by pressing the operator button,
- The shoulder enters the machine and as it travels through the machine, the shank and brisket are cut,
- The carrier stops at the neck blade position and the shoulder is measures by laser to determine the line of cut for the neck, then the neck is held by a gripper mechanism as is the shoulder and the neck is cut.



A: neck entering first with single blade for shank cuts.



B: as A but two blades cutting shank and brisket



C: approach chosen with neck trailing

Figure 4.7. Options for the cutting modules

- The operator would load another shoulder at the loading point and when pressing the operator button, the pieces already in the machine is split in two square cut shoulder pieces as the carrier indexes forward.

- The piece loaded, would go through the same process of cutting and so on and so forth.

The pieces fall on exit conveyors on both side of the carrier.

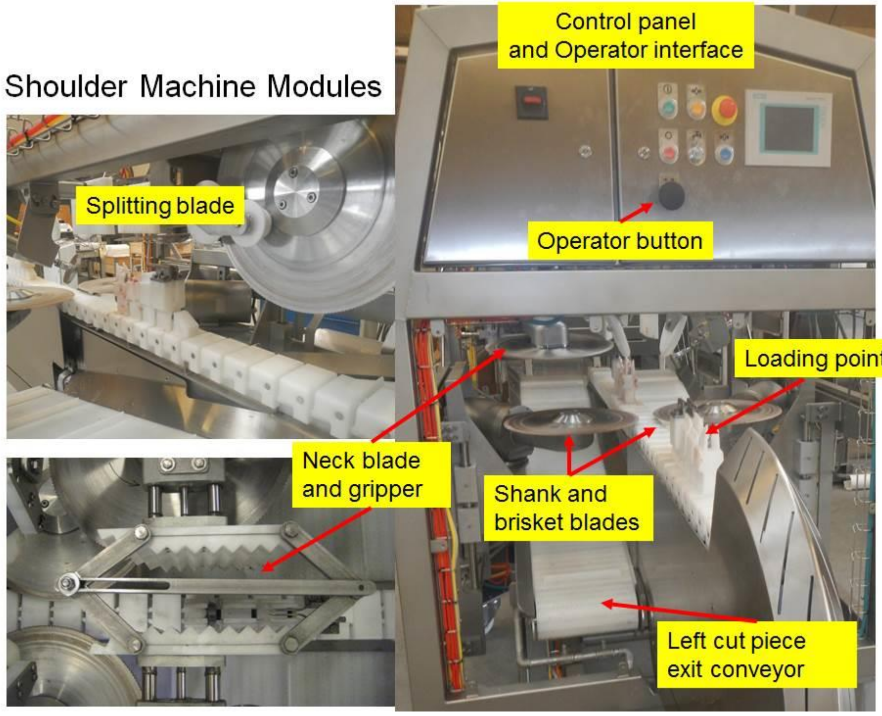


Figure 4.8. Assembled modules

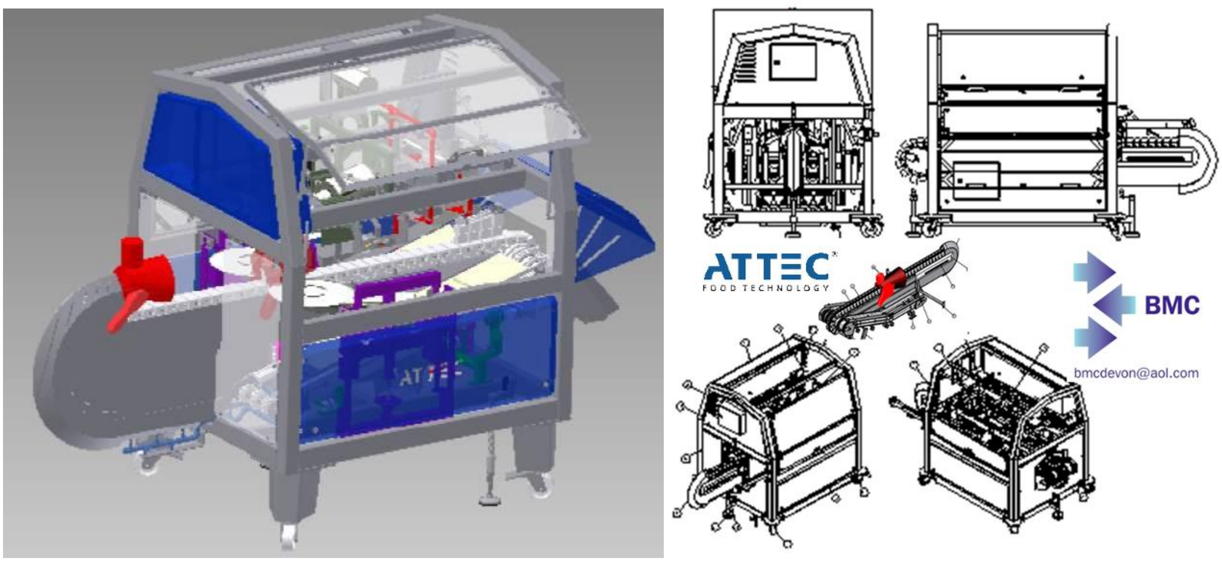


Figure 4.9. Machine overview and construction

4.4. Trials and cutting performance

After construction and initial testing at ATTEC using over 20 shoulder primal pieces, the machine was shipped to WAMMCO, WA.

The commissioning of the machine at WAMMCO has allowed trials on site to show the capability and performance.

Observations and adjustments were necessary and this was done iteratively over several months with cutting trials using over 60 shoulders of different size and shape.

After installations structured test were performed with over 40 shoulder pieces, recording the outcome on a piece by piece basis.

The machine performance may be seen in Figure 4.10 against a representative sample of cuts photographed and presented. The operating speed of the machine has been confirmed at 300 pieces or more per hour subject to operator loading speed.

Figure 4.10. Shoulder machine and resulting cuts during trials on site.

4.5. Status and the benefits

The MLA-AMPC Shoulder Machine Project has reached a mature state of development based on test results at WAMMCO in Western Australia. This marks the conclusion of the research, which has successfully reached the development results and the understanding that supports construction of a 'saleable' production machine.

The lamb shoulder cuts that may be produced from a whole shoulder primal pieces are shown in Figure 4.11. Note that the shank tip and neck tip cuts often seen performed by band-saw operators in many Australian plants were not included in this development. The main reason to exclude the shank and neck tipping relates largely to the fact that slaughter operations dealing with hock cutting of front legs and head cutting are not always performed to specification or pose hygiene issues. It is considered that the tipping tasks in the cutting room would be eliminated with the improvements in the corresponding slaughter operations and therefore any 'costly' solutions in machine development to deliver a solution including such cuts would be wasted, once slaughter improvements have been reached. The development effort would also result in a more complicated solution and an expensive machine, beyond justification.

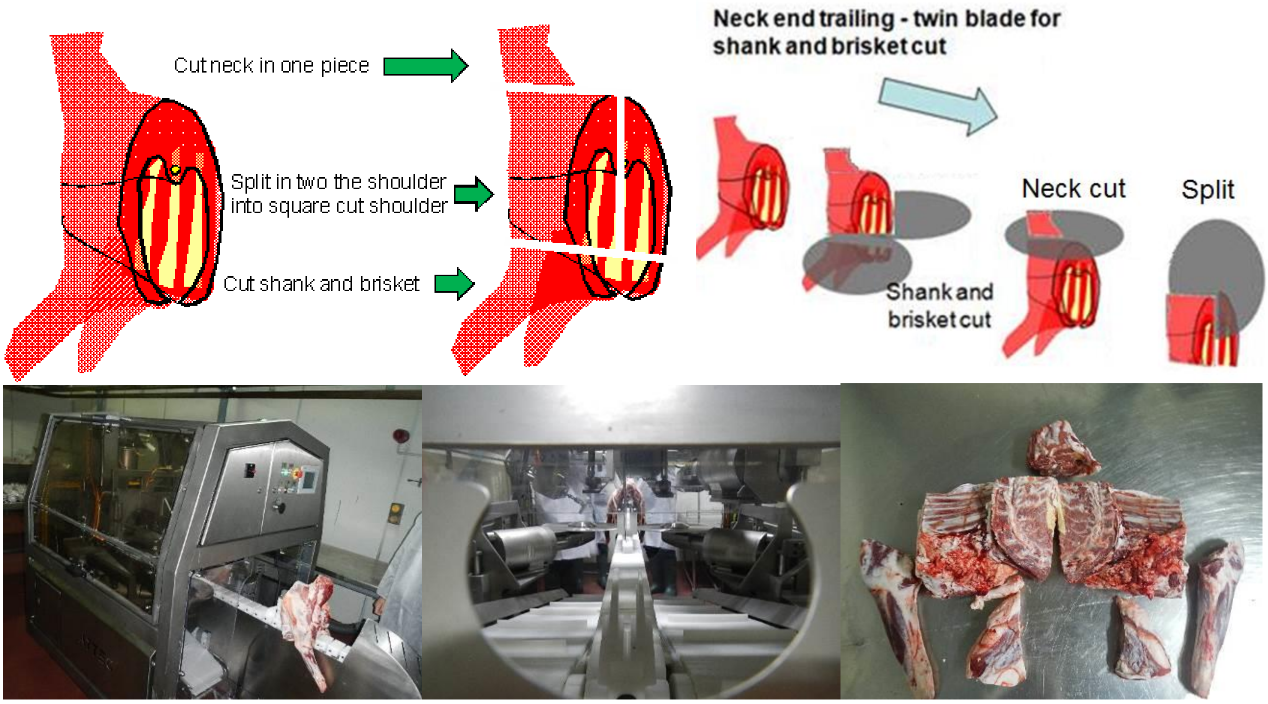


Figure 4.11: Cuts and sequence on the development machine

The Shoulder Machine has been developed for the primary and essential cuts on the shoulder including: the neck, shank-brisket cuts and splitting to products the square cut shoulder as final products. Tests indicate that the capability of the machine to achieve the correct cutting lines is as good as, if not better than, the current processes using band-saws (Figure 4.12).

The manual band-saw process requires an operator to apply significant judgement and physically lift a whole shoulder primal piece that could weigh 5-7 Kg or more.

The piece is then to be manipulated using hands and positioned in a manner that lines of the cutting line on the carcass with the blade of a band-saw.

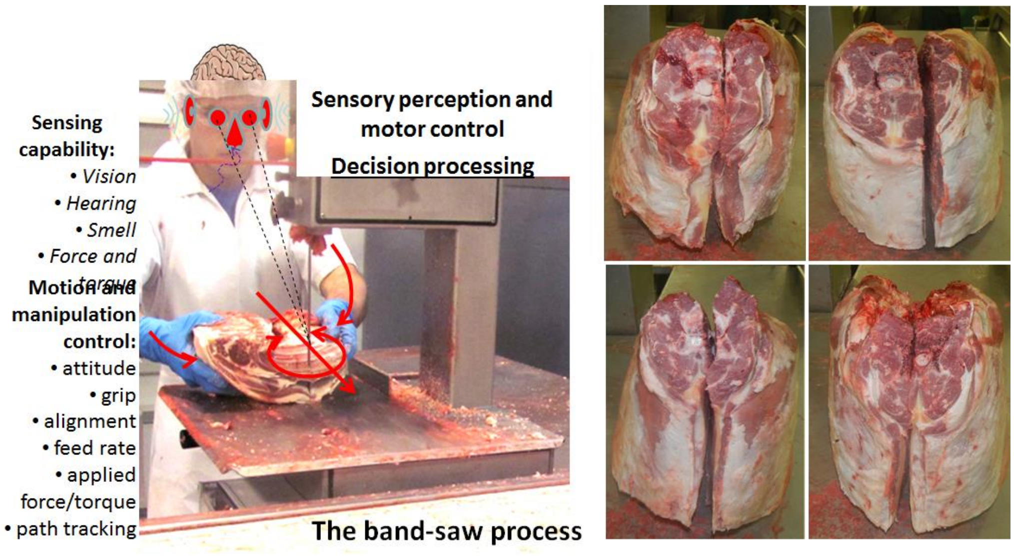


Figure 4.12: The band-saw process and examples of the splitting line of cuts (The photos on the right are representative of over 40% of the cuts observed in a short time period including time for photos)

Once the operators judges that this alignment has been reached, the shoulder piece is pushed against the saw blade to achieve the cut. The operator needs to continue a hold on all the cut pieces that require additional passes to generate the final cuts.

The splitting of the shoulder is the most difficult of the three cuts for the operator and for the Shoulder Machine, except that the shoulder machine produces an exact line of split for all shoulder pieces 120 mm into every cut. Soft-siding can occur on the shoulder machine, especially those deformed, but this is not as severe compared with the manual process. The band-saw cuts of Figure 4.12 (right) reveal this, showing the deviation of cutline for split shoulders as produced on a band-saw.

The main advantages of the machine may be summarised as follows:

- Special knife blades are used, which give benefit in quality of finish of the cut avoiding the bone dust that is generated when using band-saws,

- There knife blades also give yield gain by leaving what is nominally turned into bone dust (approximately 1 mm) on the resulting meat pieces as products.

- On the neck as well as the shank-brisket cuts, the position of the cuts may be set for best yield by the processor.

- The angle of the neck cut relative to the shoulder piece may be set for optimum result. It is noted that in some manual processes the angle at which the neck cut on a band-saw can result in significant yield losses from the square cut shoulder pieces.

- The machine distances the operator from cutting blades, unlike the band-saw process, with significant OHS improvement.

4.5. Return on investment

It is not always easy to calculate benefits that can be quantified allowing a machine performance to be translated to a return on investment. However in the case of the ATTEC Shoulder Machine, planned to be launched as commercial solution at FoodPro 2014, Melbourne, Victoria, Australia; the calculation may be based on bone dust saving from band-saws. This adds to the indirect benefits such as quality, yield optimisation by adjustment to cut positions on machine, and most important OHS by distancing the operator from the cutting blade.

Band-saws cuts produce a minimum of 1 mm bone and meat dust. To calculate the weight of a 1 mm slice of meat square cut shoulders from a small and medium size lamb were used. Note that this gives an underestimation as the lamb shoulders are normally larger and hence the losses greater when cutting by band-saw.

Figure 4.13 shows the approach to calculating losses from band-saw by separating a 10 mm thick slice on the cut faces of a square cut shoulder. The 10 mm slices were

Figure 4.13. Band-saw losses: 10 mm of meat and bone on cut faces (top left) and corresponding weights of cuts (bottom left) on one small (12-16 Kg) and one medium (17-22 Kg) size lamb square cut shoulders (top right). The resulting pieces from both sets of 10 mm cuts weighted 860 grams (bottom right).

made using a band-saw with a side guide offset away from the blade with a gap of 10 mm. The square cuts used for the calculation were from one small (12-16 Kg) and one medium (17-22 Kg) size lambs (Figure 4.13 top right). The resulting pieces from both sets of 10 mm cuts weighted 860 grams (Figure 4.13 bottom right). The breakdown of this 860 gram loss is presented for each cut face of the square cut shoulder in Figure 4.14. The calculation revels 55 grams per lamb against 1 mm as a conservative estimate.

Figure 4.14 calculation of yield gain related to a one millimetre loss of meat and bone on the square cut shoulder as produced on a band saw. It is estimated that a saving of A$ 144,000 may be expected per year at 300 shoulder primal pieces processed per hour during the year.

An important issue that has been identified by trials is the soft siding at the end of the cut in the neck region when the machine performs the splitting of the shoulder. Figure 4.15 illustrates that the end result is comparable and in most cases better than what may be observed in manual cutting using a band-saw (please cross reference to band-saw cuts in Figure 4.12 top right photos). Note that in some instance the manual cut could be completely off centre, which is not possible on the shoulder machine as all the cuts will start correctly and continue so for at least 120 mm into the cut (See Figure 4.15 right photo).

Shoulder Machine Benefits estimation					scale error ±10g	
Bone dust only against 1 mm of band-saw thickness						
	mm		grams	grams	multiple	grams
Lamb	Thick	item	weight	1mm wgt	/half	1mm wgt
12-16 Kg	10	neck	80	8	1	8
	10	shank-brisket	130	13	2	26
	10	split	270	27	1	27
16-20 kg	10	neck	40	4	1	4
	10	shank-brisket	110	11	2	22
	10	split	230	23	1	23
			Total	86		110
			Number of lambs measured			2
			Loss per lamb			55
			Round down			50
			A$ Price per Kg			5
			A$ Gain per lamb			0.25
			Machine rate		per hr	300
					A$ per hr	75
					hrs/wk	40
					AS/wk	3000
					wks/yr	48
			A$ saving per year			**144,000**

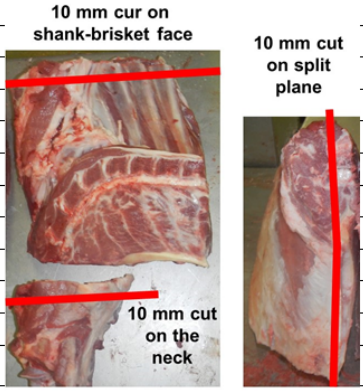


Figure 4.14. Savings per year: based on 1 mm saving against band-saw blade thickness generating bone dust on splitting, neck and shank-brisket cuts when producing square cut shoulder from a lamb shoulder primal.

Figure 4.15. Shoulder machine soft-siding in the neck region only. The cuts is in the centre of the spine for 120 mm into the cut for all cuts.

5. Concluding remarks

The project has reached its goals and has successfully tested a prototype machine (Figure 5.1) for cutting a shoulder primal into the primary product pieces including shanks and square cut shoulders. Those involved are grateful for MLA and AMPC support for this highly industry focused development.

Figure 5.1. ATTEC Shoulder Machine

Test show that the machine is capable of less than 24 months return on investment at a market selling price of AU$ 280,000. This has been a significant achievement, given that the savings do not account for benefits relating to OHS, quality and shelf life and yield optimisation.

The running costs of the machine are considered low (less than 3% per year of the cost of the machine. The life of the machine is estimated at 15-20 years subject to the maintenance policies and practices of the host plant. This is achieved through design and selection of components, which ATTEC Denmark have long experience with, when designing other machines already been in use in the meat sectors.

It is proposed that a follow up project relating to adoption specifies the performance characteristics of the machine and in a 12 month production observation, documents the parameters of interest to processors, such as life of blades, failure types and frequencies, cost of repair and running costs. Aspects of competence in operation, maintenance would also be observed and reported.

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