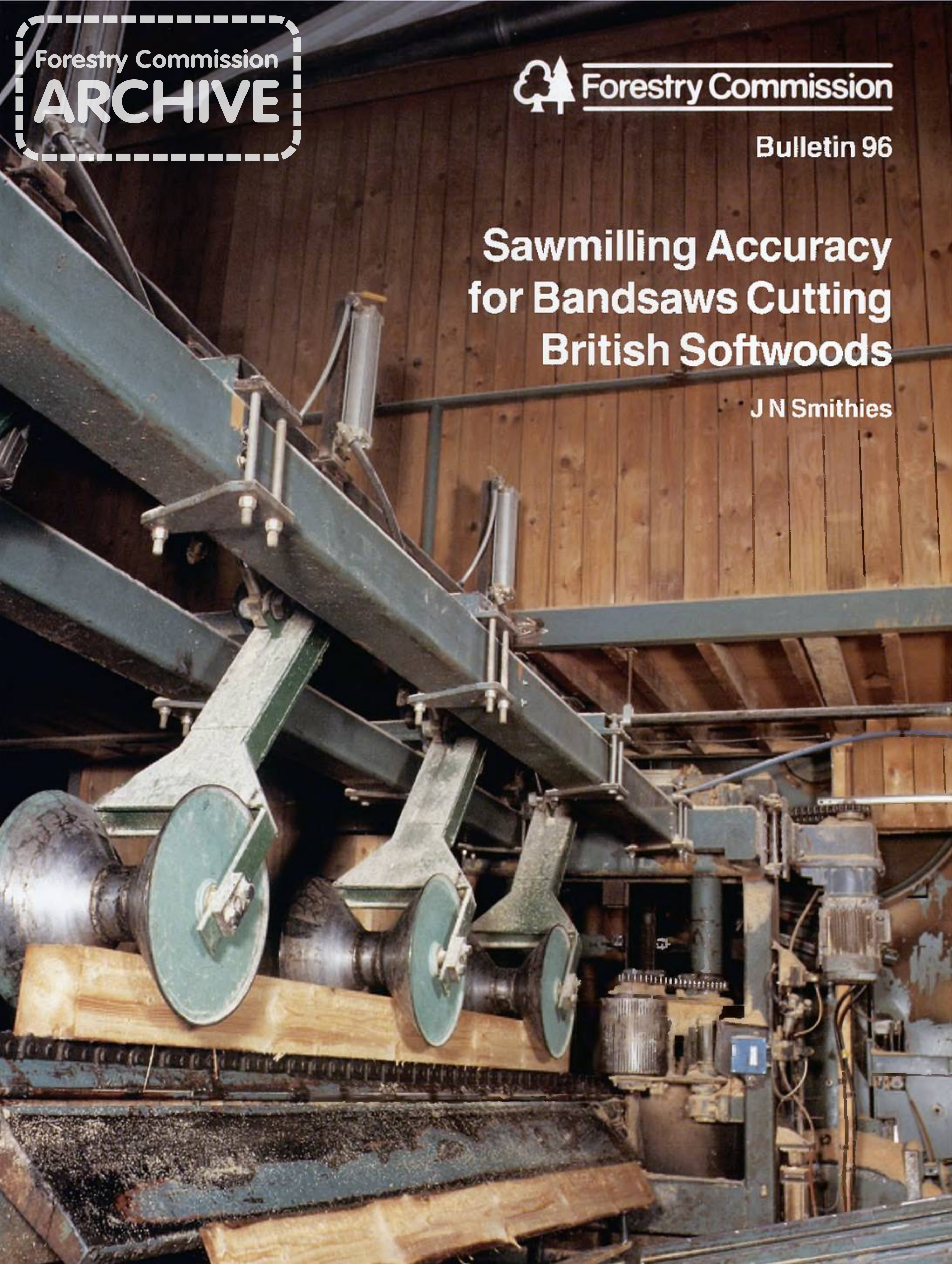
Forestry Commission

Bulletin 96

Sawmilling Accuracy for Bandsaws Cutting British Softwoods

J N Smithies



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Sawmilling Accuracy for Bandsaws Cutting British Softwoods

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Building Research Establishment

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Front cover: Softwood timber sawn to specified size at the BSW sawmill, Newbridge-on-Wye. *(40081)*

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Sawmilling Accuracy for Bandsaws Cutting British Softwoods

Summary

The dimensional accuracy with which timber is sawn is important both for its marketability and for its economic production.

This Bulletin describes quality control techniques that can be used for sampling and measuring sawn timber taken from the production line in softwood sawmills. The dimensions obtained from the measuring process can be used to quantify and analyse the accuracy with which timber is being produced in the sawmill. The results obtained from the analysis of the measurements can then be used to give pointers as to which part of the production line should be examined to improve or optimise the sawing accuracy.

Reasons for variation in dimensions both *within* pieces of timber and also *between* pieces of timber are examined for bandmills, reducer bandsaws and resaws. Machine and sawblade characteristics covered include: tooth geometry, sawblade strain and tension, sawguides and feed speed. Particular attention is given to problems that can arise when sawing relatively quickly grown low density timber, which contains hard knots, such as British-grown Sitka spruce.

Sawblade parameters that have been found to work well with low density softwood are given and a check-list of items which should be observed to achieve accurate dimension when sawing British-grown Sitka spruce is provided.

Précision Obtenue lors du Sciage des Bois Résineux Britanniques par des Scies à Ruban

Résumé

Le degré de précision obtenu lors du sciage du bois détermine non seulement les chances de commercialisation de celui-ci mais aussi la rentabilité de la production.

Ce Bulletin présente des méthodes de contrôle de la qualité, qui peuvent être utilisées pour l'échantillonnage et le mesurage du bois de sciage, celui-ci étant prélevé directement au niveau de la chaîne de production, dans les scieries à bois résineux. Les dimensions obtenues lors du mesurage sont utilisées pour évaluer et analyser le degré de précision réalisé lors de la production du bois, dans la scierie. Ensuite, les résultats tirés de l'analyse des mesures peuvent être utilisés pour déterminer quelle partie de la chaîne de production devrait être modifiée afin d'améliorer ou d'optimiser la précision de sciage.

Les raisons expliquant les variations dimensionnelles relevées dans les morceaux de bois aux-mêmes mais aussi lors de la comparaison entre plusieurs morceaux, sont étudiées pour chaque outil: scies à ruban principales, scies à ruban secondaires et scies à refendre. Les caractéristiques examinées sur les machines et les lames de scies sont la géométrie des dents, la tension du ruban, les guides de lames et la vitesse d'alimentation des machines. Une attention particulière est portée aux problèmes pouvant survenir lors du sciage des bois peu épais à croissance rapide, contenant des noeuds durs, comme l'épicéa Sitka, qui pousse en Grande-Bretagne.

Certaines caractéristiques spécifiques propres aux lames de scies et particulièrement adaptées à la coupe des bois résineux peu épais, figurent dans ce Bulletin. En outre, celui-ci présente une liste d'éléments dont l'application permet d'obtenir des dimensions exactes lors de la coupe des épicéas Sitka, originaires de Grande-Bretagne.

Die Sägegenauigkeit von Bandsägen beim Sägen von Britischen Nadelhölzern

Zusammenfassung

Die Maßhaltigkeit, mit der Holz gesägt wird, ist für seine Marktfähigkeit sowie für seine wirtschaftliche Herstellung von Bedeutung.

Dieser Bericht beschreibt Qualitätskontrollmaßnahmen, die zur Probenahme und Messung von Schnittholz, das vom Produktionsband in Nadelholzsägewerken entnommen worden ist, angewandt werden können. Die beim Meßvorgang festgestellten Maße können zur quantitativen Bestimmung und Analyse der Genauigkeit, mit der Holz in den Sägewerken produziert wird, verwendet werden. Die bei der Meßanalyse gewonnenen Ergebnisse können dann Hinweise darauf geben, welcher Teil des Produktionsbereichs untersucht werden soll, um die Sägegenauigkeit zu verbessern oder optimieren.

Die Gründe für die Maßvariationen bei Holzstücken sowie zwischen Holzstücken werden bei Hauptbandsägen, Trennbandsägen und Trennsägen untersucht. Die behandelten Maschinen- und Sägeblattcharakteristika sind u.a.: Zahngeometrie, Sägeblattspannung, Blattführungen und Vorschubgeschwindigkeit. Besondere Aufmerksamkeit wird den Problemen geschenkt, die entstehen können, wenn man relativ schnell gewachsenes Holz mit einem niedrigen Dichtigkeitsgrad sägt, das harte Knoten hat, wie z.B. die in Großbritannien gezogene Sitkafichte.

Sägeblattparameter, die sich bei Nadelhölzern mit niedriger Dichtigkeit gut bewährt haben, werden aufgeführt, und außerdem steht eine Checkliste von Punkten, die man beim Sägen von in Großbritannien gezogener Sitkafichte in Betracht ziehen soll, zur Verfügung.

Sawmilling Accuracy for Bandsaws Cutting British Softwoods

*J. N. **Smithies**, Department of the Environment, Building Research Establishment*

Introduction

The dimensional accuracy with which timber is sawn is important both for its marketability and for its economic production. The customer requires and expects consistent thickness and width dimensions not only along the length of a piece of timber but also between pieces of timber and between parcels of timber.

Excessive variation in dimensions often means that timber has to be sawn oversize and may result in the timber being rejected by the customer, or it may necessitate the timber being 'regularised' to produce uniform dimensions before it can be used. If the timber is undersize, due to sawing variation or poor machine adjustment, it may be necessary to resaw it to a size smaller. When timber is to be machine stress graded, dimensional accuracy and consistency are particularly important both for customer acceptability and also for correct performance of the stress grading machine *(BS 4978)*.

British sawn softwood has to compete directly with imported softwood, and in order to do this effectively it should be sawn with comparable accuracy. This Bulletin discusses the factors which influence dimensional variation, and suggests ways in which sawing accuracy can be optimised.

Quality control

Production performance is currently measured in terms of production rate and sometimes conversion yield but dimensional accuracy is of equal importance. A significant step towards improving accuracy lies in *quality control*.

In order to control or improve sawing accuracy it is necessary for production management to know how accurately the timber is being sawn. This requires precise and detailed sawn timber measurements to be taken from samples pulled off the production line at intervals during each shift, and for records of the measurements to be kept. The output from each saw should be sampled by taking measurements for each production run or shift. In the case of multiple saws in particular, the sampling should be done so that it is possible to identify which saw or pair of saws has produced each board.

Detailed information concerning the development of quality control techniques, sampling, measuring, assessing sawing accuracy and other aspects are available from several sources (Allen, 1976; Brown, 1982; Lemaster, 1984; Steele *et al.*, 1986) and are all broadly similar. Typically these require measurements on ten pieces of timber for each size produced and that at least five thickness measurements should be

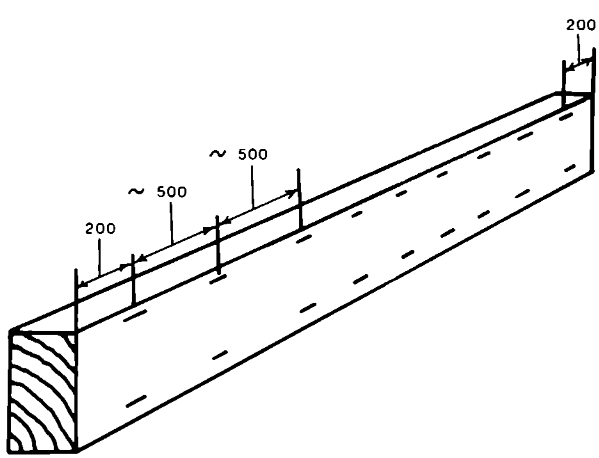


Figure 1. Sampling details showing 10–20 samples per piece depending on length (sampling distances in mm).

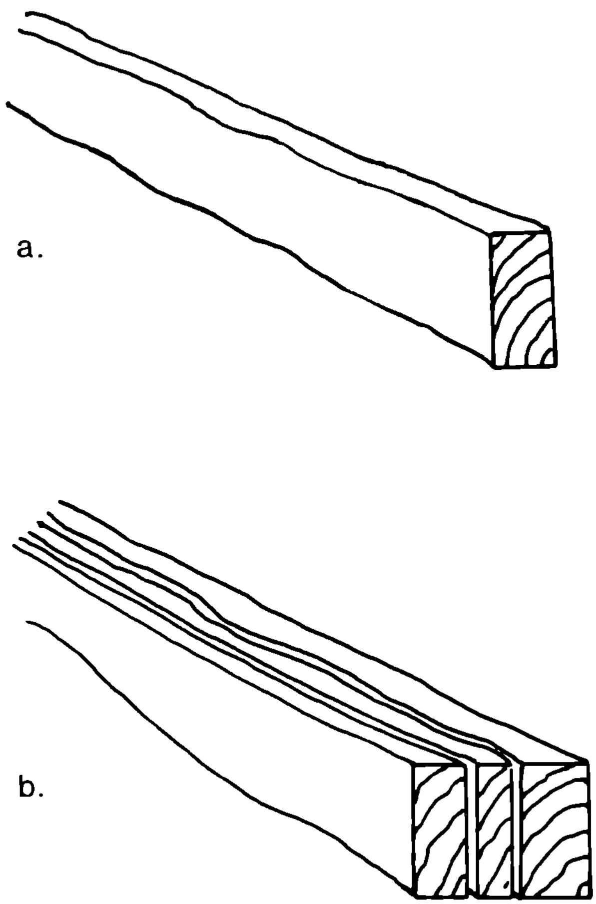
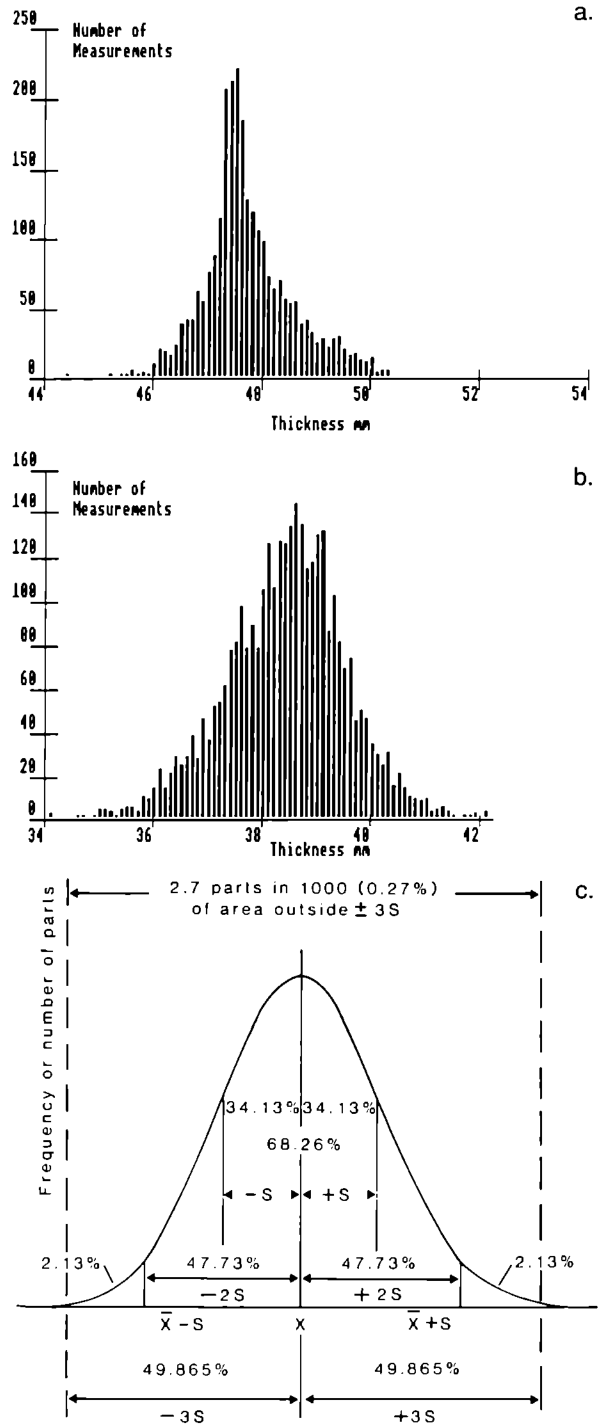


Figure 2. Variation in dimensions, (a) 'within' and (b) 'between' pieces.

taken along each edge of the timber (Figure 1). This is an accepted measuring technique which enables an ongoing statistical analysis of sawing accuracy to be built up. The measurements should be taken using calipers having an accuracy of ± 0.01 mm or better; these may be dial guage or vernier calipers or may be an electronic digital type with a memory pack to store the readings.

The overall accuracy with which pieces of timber are sawn can be subdivided into two groups – the variation in dimensions *within* individual pieces of timber and the variation in average dimensions *between* pieces of timber (Figure 2). This produces three sets of measurements – 'within piece' variation, 'between piece' variation and 'overall' variation. For each piece of timber the average thickness, thickness



Distribution of variation in green sawn timber production

Figure 3. Sawn timber dimensions, (a) with a standard deviation of 0.35 mm, (b) with a standard deviation of 0.6 mm, (c) standard deviation of product dimensions.

range and standard deviation of the measurements can be calculated – (standard deviation is a measure of the variation about the average value of a series of measurements and can be calculated from formulae given in the Appendix). These individual standard deviations for each piece of timber measured, can then be combined at the end of the shift or week to give a total 'within piece' standard deviation for the timber produced.

Figures 3a & b show examples of the range of thickness produced in two British sawmills, giving within piece standard deviations of 0.35 mm and 0.6 mm. The 'within piece' standard deviation of 0.35 mm represents the standard set by the best British sawmills and is comparable with imported material.

The 'within piece' and 'between piece' variations can be statistically combined to give the 'overall standard deviation'. This is a measure of the overall performance of the production line. Figure 3c is a diagram which illustrates the meaning of standard deviation, showing that 68% of the green sawn timber production can be expected to be within ± 1 overall standard deviation either side of the average product dimension; 95% of the dimensions of its green sawn timber production can be expected to be between ± 2 overall standard deviations either side of the average product dimension, and virtually all of the production will lie within the range of ± 3 overall standard deviations. Conversely, whilst virtually all production is within 3 standard deviations of the average, 5% of the production will be outside the limit indicated by 2 standard deviations and 34% of the production will be outside the limit indicated by 1 standard deviation either side of the average thickness. An example of how to handle measurement is given in the Appendix.

A quality control system should be implemented to enable sawing accuracy to be measured and controlled to a high standard.

Improvement of sawing accuracy

The causes of between piece variation and within piece variation are different and require separate considerations. In a quality controlled sawmill the between piece variation should be less than the within piece variation.

Sawing accuracy between pieces

Traditionally, with bandmills and band resaws, the between piece variation is a measure of the repeatability of the setworks. In the case of modern saw lines and reducer bandsaws in particular, the 'between piece' variation will often be a measure of the different dimensions coming from different saws cutting the same product size; this is caused by the saws being positioned or set inaccurately at the beginning of the production run. In other mills it is often a measure of the two different dimensions of nominally identically sized pieces of timber coming from a split saw with fence set exactly to the dimension required, and not half the dimension of the timber being sawn into two pieces – taking saw kerf into account as well of course.

Between piece variation can be attributable to many factors including:

- mechanical play in feed works systems,
- mechanical play in setworks,
- lack of repeatability of setworks,
- mis-adjustment of setworks,
- mis-adjustment of pressure sawguides,
- mis-alignment of feed system.

It can be reduced to acceptable levels by introducing a quality control programme. This pays close attention to the initial dimension setting on all of the machines in the production line and regularly monitors the sawn timber dimensions in such a way that they can be traced back to individual saw settings, enabling remedial action to be quickly carried out by adjusting the correct setworks.

This type of quality control can be achieved by using either sawmill personnel recording spot dimension checks along the pieces of timber, as indicated earlier in this report, or an 'on-line' automatic measuring station which gauges the dimensions along the length of each piece of timber. The measuring systems currently in use for dimension sorting of sawn timber check thickness at only one point along the length of the piece of timber and so are not suited to a quality control application such as this.

Mis-adjustment of the setworks and wear in pressure guides account for most of the 'between piece' variation encountered in modern British sawmills. Instances of machine misalignment have been encountered but were usually associated with setworks problems. Mechanical play in well maintained mills is very rare and it is often the case that though the actual settings are highly repeatable the setworks are not correctly adjusted. The high level of repeatability of the setworks indicates that it should be possible to achieve 'between piece' variations which are less than the 'within piece' variation encountered in the better mills.

Sawing accuracy within pieces

General considerations

Quality control techniques covered in the previous section also highlight the 'within piece' variation. Improvement of 'within piece' sawing accuracy can be quite complex and less straightforward than improvements in 'between piece' variation. It requires some understanding of the way in which a bandsaw functions and the way in which the blade and machine system interact with the timber. Figure 4 shows a simplified schematic diagram of a bandsaw and bandsaw blade with pressure guides. The system is shown with a traditional weight/lever strain mechanism and also with a more recent pneumatic and/or hydraulic strain system.

There are many machine/sawblade factors which, if incorrect, can cause the sawblade to deviate and hence affect the dimensions within a piece of timber. These include:

sawblade strain and tension,
tooth shape and pitch,
gullet loading/feed index/feed speed,
machine alignment,
type of strain system,
infeed system.

Sawblade strain and tension

A state of dynamic equilibrium or balance must exist for a bandsaw to be able to cut timber in a straight line without the blade wandering from side to side or being pushed off the saw pulleys.

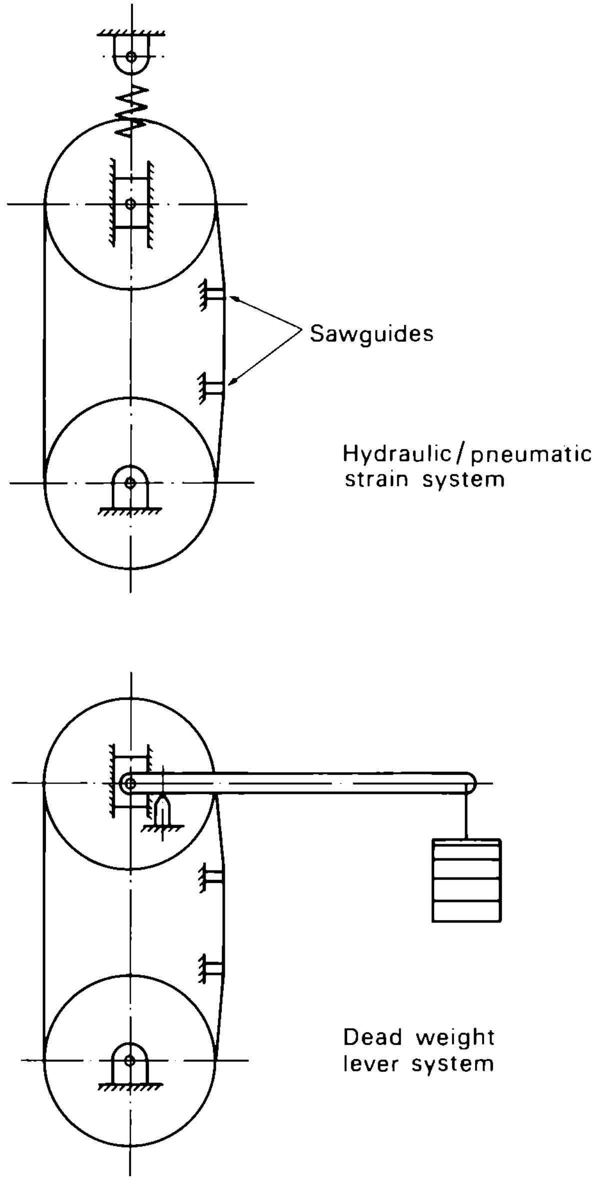


Figure 4. Essential components of bandsaw straining and guiding system.

Considerable heat is generated by the flexing of the sawblade over the pulleys, by contact with the saw guides, and by the work that the teeth do in cutting the timber. The cutting edge of the saw must remain 'tight'. If it does not, then the sawblade will wander from side to side and the 'within piece' sawing accuracy will be poor. Saw blade rolling/tensioning, saw strain and slight tilting of the top saw pulley are used to keep the cutting edge of the saw in tension and the saw

Plate 1. _An essential element of accurate sawing is the good maintenance of sawblade tension through the top pulley, saw teeth configuration and sawguides._ (Building Research Establishment 90.223.1)

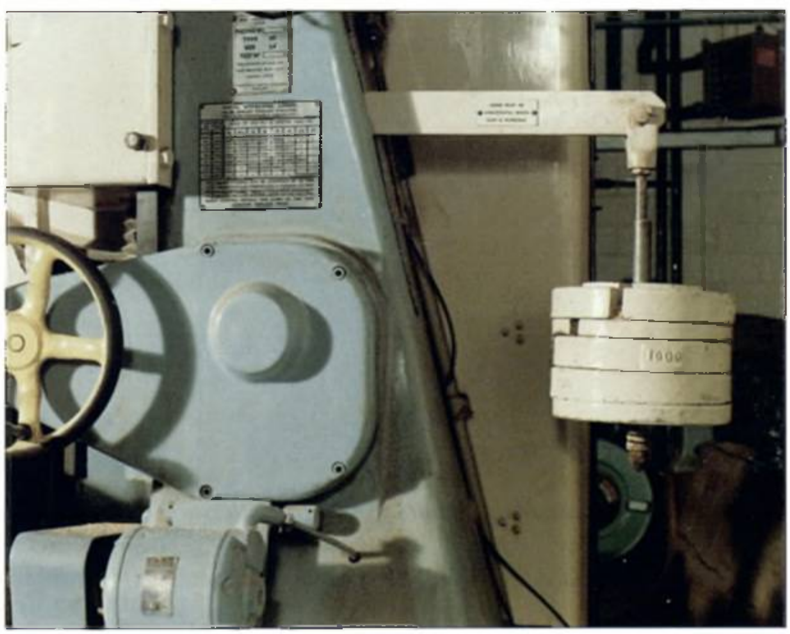


Plate 2. _Proper tensioning of the sawblade ensures that it runs in the correct position over the top pulley._ (Building Research Establishment 90.104.4)

Plate 3. *Fully functioning pulley cleaning ensures even sawblade strain and position during operation.*
(Building Research Establishment 87.407.7)

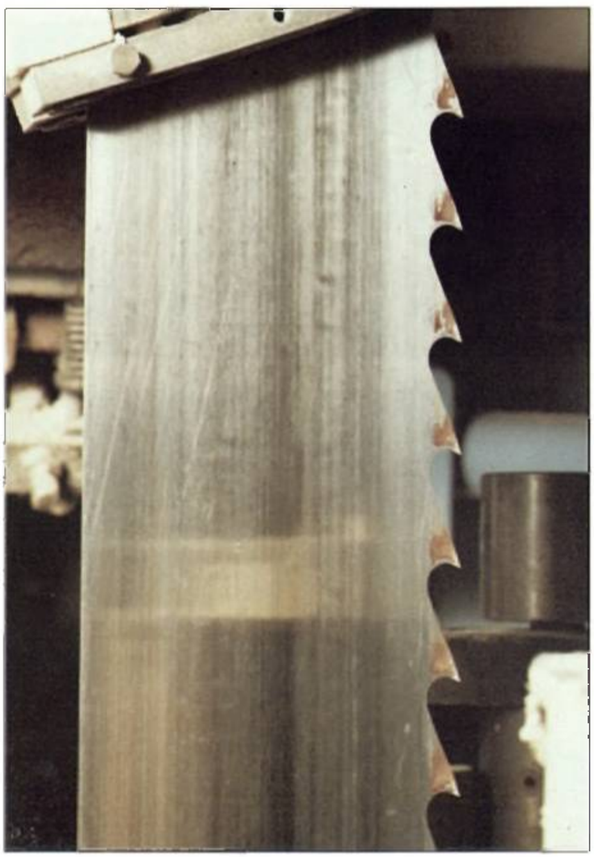


Plate 4. *An example of 'S' shaped teeth with a hook angle of 25°.*
(Building Research Establishment 87.407.2)

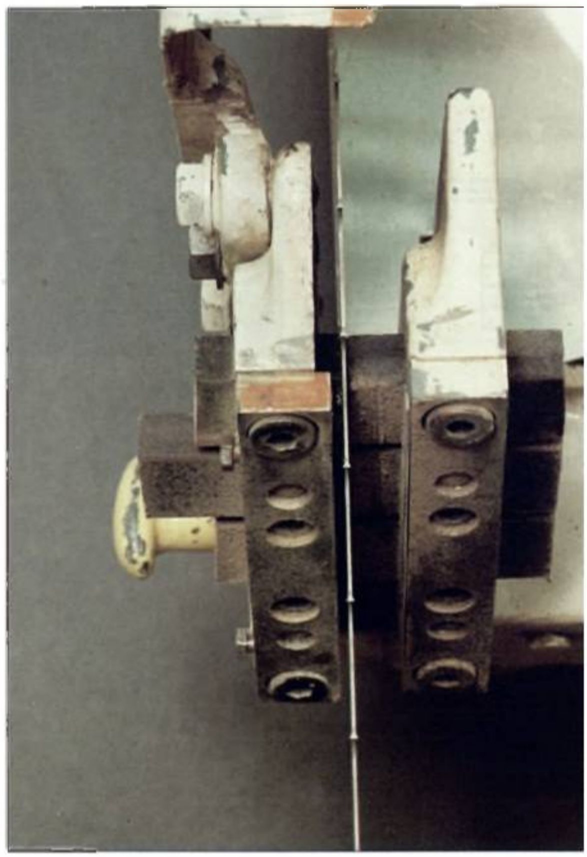
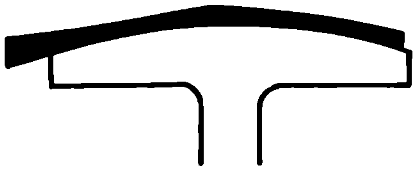


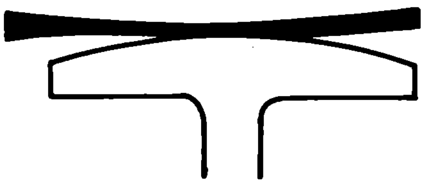
Plate 5. *Sandwich guides are designed to be non-contacting; they stabilise the sawblade after deflections have occurred during sawing.*
(Building Research Establishment 87.407.3)

a.



Correct tensioning

b.



Incorrect tensioning

Figure 5. Effect of tensioning on contact between sawblade and pulley.

running in the correct position on the pulleys.

Rolling or tensioning is the name given to the process of physically elongating the centre portion of the sawblade so that the blade becomes slightly arched in cross section when it is bent round the saw pulleys. This causes the front and back portions of the blade to grip the saw pulleys (Figure 5). It is achieved by passing the centre portion of the blade through a pair of narrow hardened metal rollers which plastically deform the blade, leaving a residual tensile stress in the front and back edges of the saw and consequently compressive stresses in the central portion. This ensures that the cutting edge will still be in a state of tension when the saw is cutting and is warm. Too little tension will leave the blade in an unstable state when it is cutting. Too much tension will tend to cause the blade to crack at the gullets due to the concentrated localised forces caused both by the saw strain mechanism and the continual flexing of the blade over the pulleys.

Rolling or stretching of the sawblade continues to be a substantial part of the skill of saw doctoring (Simmonds, 1980). Machines have been developed which will semi-automatically roll and tension a bandsaw blade to a required degree of curvature, but there is no satisfactory way of accurately measuring the stress levels which have been achieved in the rolling process.

Strain is the term used to refer to the upwards vertical force which is applied to the top pulley and keeps the sawblade in a state of tension in the true mechanical sense. Strain levels in use result in static stresses in the sawblade of between 500 kg cm^{-2} to 1250 kg cm^{-2}. The degree of tensioning and amount of strain required depend upon several factors including:

sawguide and width,
pulley diameter,
degree of crown on pulleys,
robustness of the mechanical design of the saw, e.g. standard strain or high strain.

Machinery manufacturers' recommendations and figures quoted in the literature are usually modified by individual saw doctors to suit local circumstances.

The sawblades must be benched and levelled frequently to ensure that they are in good condition and free from cracks, bumps and hollows. The degree of tension in the sawblade should be in line with the manufacturer's recommendations and be matched to the crown on the pulleys and strain level in use.

Sawguides

Sawguides are used to restrain the sawblade and so improve its resistance to twist and deflection. Two types of sawguide are in common use – non-contacting sandwich guides and pressure guides. The rigidity or stability supplied by the guides to the sawblade is affected by the distance the guides are apart; this distance should be minimised to maximise the effectiveness of the guides.

Sandwich guides are designed to be non-contacting and to stabilise the saw when it is deflected. They are usually adjusted to the thickness of a sheet of paper away from contact with the sawblade.

Pressure guides typically deflect the sawblade by 10 mm and exert considerable additional bending stress on the sawblade. Pressure guides produce a significant amount of frictional heat but they produce a system which is more resistant to sideways movement than is the case with sandwich guides. However, pressure guides must be well maintained as they directly affect the sawn timber dimensions and the alignment of the sawblade. They tend to wear or be damaged in the vicinity of the sawteeth – this applies a 'lead' to the sawcut which can make the sawblade wander and give variable sizing to the timber.

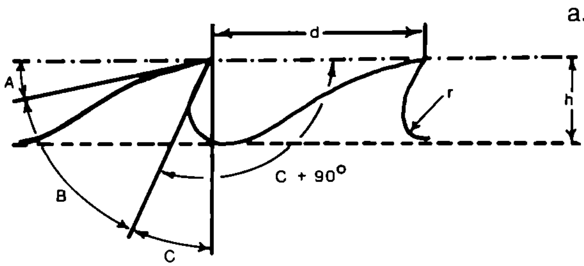
Sawguides should be checked for wear and adjustment each time the sawblade is changed. When pressure guides are fitted considerable advantages can be gained by the use of cartridge guides which can be reset and refaced off the machine. In high production mills using this system the sawguides can be changed daily.

Tooth geometry

The care with which a sawblade is prepared, stored and handled has a major effect not only on accuracy but also on the surface finish and hence presentation of the sawn timber. Sawtooth shape characteristics are particularly important to the performance of the production line. An outline of the sawtooth and the terminology used for the various parts of the tooth is shown in Figure 6a. The more important aspects of tooth geometry are considered below.

Hook angle

This is of paramount importance as it directly affects the feed rate and hence production capacity of the saw. Wide bandsaw blades typically have teeth with swaged tips (Figure 6b). This type of tooth, in effect, chisels its way into and through the timber. If the hook angle is too small, then the tooth will tend to rub against the timber rather than cut it and the saw will be pushed back on the pulleys by the feeding action of the timber. If the hook angle is too large, then the tooth will tend to pull itself into the wood; if this tendency is not balanced by the feed speed then the saw will move forwards on the pulley as the teeth bite into the timber. This will tend to increase the bite per tooth, the rate at which work is done and consequently the power consumption. A hook angle of 25-30 degrees has become the standard when sawing softwoods.



The shape of the tooth line is determined by the following characteristics:

d = pitch
h = depth of gullet (tooth height)
r = root radius
A = clearance angle
B = tooth angle
C = hook angle

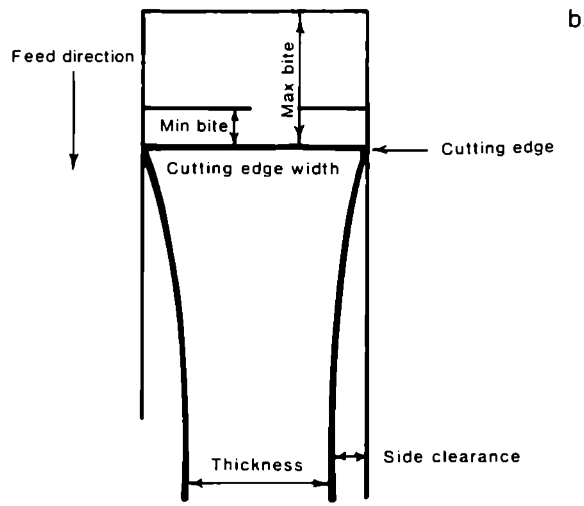


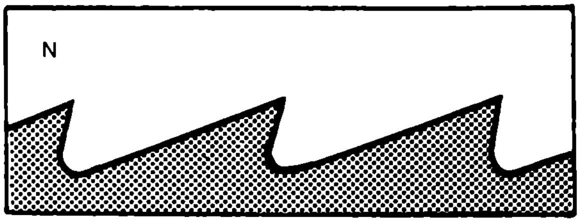
Figure 6. Nomenclature for saw tooth geometry.

Clearance angle

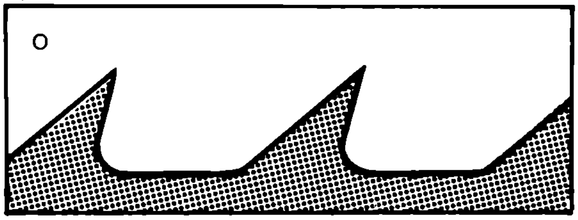
This exists to prevent the back of the tooth rubbing against the timber which would otherwise cause friction and overheating. Excessive clearance angle results in a reduced tooth angle which causes the tooth to blunt more quickly. Empirically the clearance angles used range between 5 and 10 degrees.

Tooth pitch

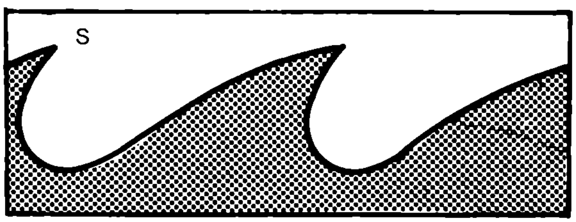
This is the distance from tooth point to tooth point. Primarily it determines how much cutting work a saw can achieve but tooth pitch has to be related to gullet capacity. Tooth pitch is



Shape 'N' is generally used for narrow bandsaw blades, i.e. widths up to 50 mm (2"). It is a strong tooth, which can be recommended for excessively hard woods. The gullet area is comparatively small.



Shape 'O' has a flat-bottomed gullet and a large gullet area. It is recommended for timbers with a coarse and stringy grain and generally for soft woods. In the opinion of many saw doctors, the flat-bottomed gullet reduces the risk of cracks at the base of the gullet.



Shape 'S' is the usual shape for wide bandsaw blades, especially those with swaged teeth. Because of the convex back the clearance angle is reduced to a minimum.

Figure 7. Basic saw tooth shapes.

normally increased for wider blades, higher sawing speeds and deeper cuts as it enables the gullet capacity to be increased. Increasing the pitch tends to lower the power consumption. Closer pitch improves surface finish and increases the cutting life of the tooth, as each tooth is doing less work for a given length of timber sawn, but the tooth pitch also interacts with feed rate and sawdust particle size. In Britain tooth pitch tends to range between 35 and 50 mm. The effect of tooth pitch and feed speed on gullet shape and sawdust particle size is covered more fully under the heading of feed speed.

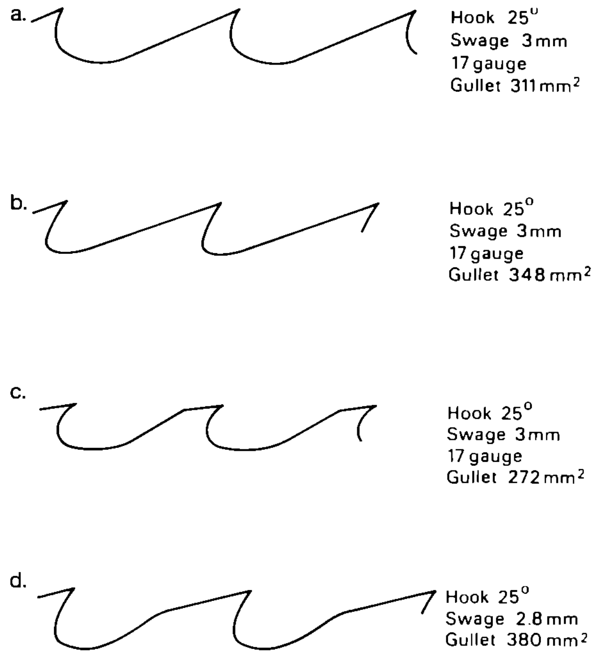


Figure 8. Saw tooth profiles encountered in British sawmills producing 'within piece' standard deviations of less than 0.45 mm.

Gullet

This is the portion designed to remove the sawdust from the cut. The volume of the gullet is affected by tooth height, tooth shape and tooth pitch. A compromise must be reached concerning gullet capacity and tooth rigidity – if the teeth are too high they will tend to flutter, this causes vibration and produces an unnecessarily wide kerf. There are several empirical rules for tooth height ranging from 25% of the pitch in the UK and the rest of Europe, to 50% of the pitch of North America where thicker gauge saws used to be the standard (Anon., 1976; Lunstrum, 1985; Williston, 1978).

There are three basic gullet/tooth shapes. These are shown in Figure 7. They have a wide range of gullet volume for a given tooth pitch and kerf. Figure 8 shows the range of tooth shapes encountered in four of the more accurate British sawmills. Most British softwood mills tend to use a variation of Figure 7 tooth type S (Figures 8a,c,d). Well rounded gullets with a reasonable sawdust capacity and good clearance angle such as tooth (a) in Figure 8 have been found to give good results with British-grown Sitka spruce.

Swage/kerf

The tip of the tooth is made wider than the body of the saw so that the sides of the blade will not rub in the cut and generate heat which in turn will lead to instability and saw snaking. Traditionally the amount of swage required has been found by trial and error to be linked to saw gauge or thickness and to some extent saw blade width. Swage is also linked to timber density and moisture content.

The timber fibres are compressed as they are being sheared or cut, they then spring back to some extent after the cutting forces have been removed. The swage should be sufficient to ensure that there is still sufficient side clearance for the blade not to be rubbing the sides of the cut after the fibres have recovered. Softwoods in general, particularly when dry, tend to be more stringy, fibrous and compressive and are difficult to cut cleanly. Excessive side clearance wastes timber, increases power consumption and may cause the sawtooth to be overstressed which in turn may cause instability of the sawblade.

Research at the Building Research Establishment has shown that side clearance is a very important consideration when sawing British-grown Sitka spruce – this is illustrated in Figure 9. It has been found that the swaging and side dressing needs to produce a strong tooth tip and very even swage. Preferably the standard deviation of the tooth swage (see footnote) should be less than 0.05 mm; commercially serviced saws are up to 0.2 mm standard deviation on saw tooth swage. Pneumatic swagers have been found to give good results. Not only must the swage be very even but it must also give the blades sufficient side clearance. Sawdust has very low monetary value compared to sawn timber so the emphasis is on reducing the kerf as much as possible. Sawing accuracy problems in several sawmills have been found to be caused by inadequate side clearance. Table 1 lists the tooth pitch, saw gauge, swage and side clearance encountered in British mills using reducer bandsaws. Recommended clearances as given in text books and manufacturers literature are also included in Table 1.

Close attention should be paid to all aspects of tooth geometry. The gullet should be well

The standard deviation for the variability of sawtooth thickness should be carried out by measuring the thickness of each tooth and applying the formula in the Appendix for calculating the 'within piece' standard deviation.

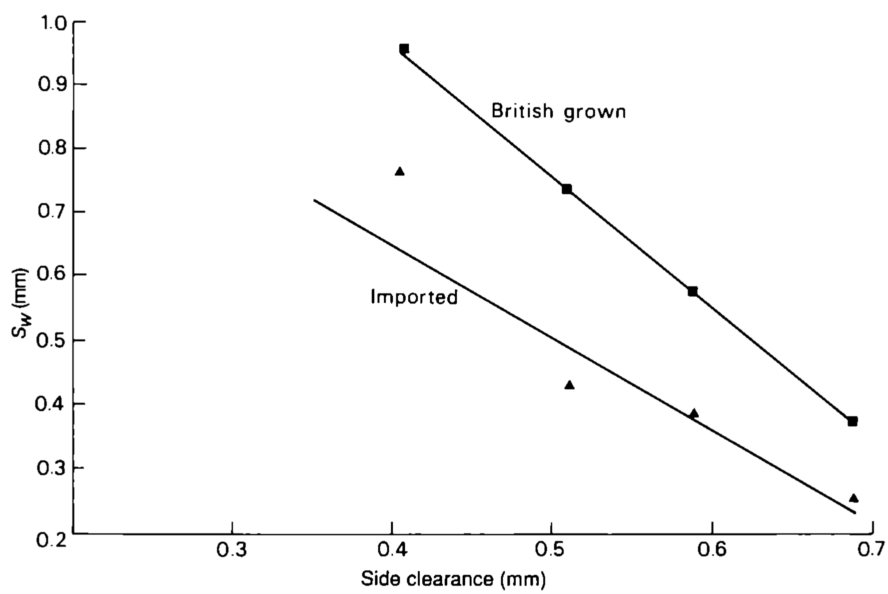


Figure 9. 'Within piece' standard deviation (S_W) vs blade side clearance when sawing Sitka spruce.

Table 1. Tooth pitch, sawblade thickness and side clearance encountered in sawmills during accuracy survey

Tooth pitch (mm)	*Blade thickness[a] (mm)*	*Swage (mm)*	*Side clearance[b] (mm)*
40	1.47	3.0	0.76
45	1.65	3.6	1.02
50	1.24	2.5	0.61
50	1.24	2.5	0.61
50	1.47	3.5	1.01
50	1.47	3.2	0.86
40	1.06	2.3	0.62
40	1.47	3.0	0.76
50	1.65	3.5	0.92
40	1.47	3.5	0.7
40	1.24	2.7	0.72
40	1.47	3.2	0.86
45	1.24	2.5	0.62
45	1.47	3.0	0.76
45	1.24	2.7	0.72
45	1.47	2.65	0.59
45	1.47	2.78	0.66

a 1.06 mm = 19 gauge
1.24 mm = 18 gauge
1.47 mm = 17 gauge
1.65 mm = 16 gauge

b These figures give a clearance of 0.6 to 1.0 mm – a typical figure encountered is 0.76 mm.

Recommended clearances for softwood:

Sandvik	0.5 – 0.6 mm
Williston	0.5 – 0.7 mm
Koch	0.5 – 1.0 mm
Lunstrum	0.86 mm
Uddeholm	0.5 – 0.6 mm
Allen	0.8 mm

rounded and of adequate capacity. The hook angles should balance the feed rate and density of the timber. It is recommended that a very even swage should be used which gives a side clearance of at least 0.75 mm per side when sawing dry British-grown Sitka spruce.

Feed speed

Feed speed directly influences sawing accuracy – too high a feed speed can result in poor accuracy due to overloading the gullet. Too low a feed speed can lead to spillage of the fine sawdust produced by the low speed which again can lead to overheating of the sawblade. Feed speed of course also affects power consumption and forces exerted on the saw, the heat generated by the saw and the particle size of the sawdust.

The particle size of the sawdust is important because it can affect the degree of frictional heat generated between the saw and the sides of the sawcut. Sawdust is intended to be carried away from the cut by the gullet. If the particle size of the sawdust is too small then the sawdust tends to fall out of the gullet and pack the space between the sides of the cut and the saw. This increases the amount of friction and leads to instability in the saw through overheating and loss of tension. If the feed speed is too high or the depth of cut is too great then the gullet is overloaded. Again this leads to spillage and packing of sawdust between the sawblade and the sides of the cut with subsequent overheating of the saw and loss of stability.

Minimum feed speed

To avoid the sawdust falling out of the gullet and becoming trapped between the sides of the saw and the timber, the sawdust particle size should be larger than the clearance gap produced by the swage of the saw tooth. The sawdust particle size is directly related to the tooth bite (Figure 10). In a typical reducer bandsaw mill with 17 gauge saws and a 3 mm kerf, the

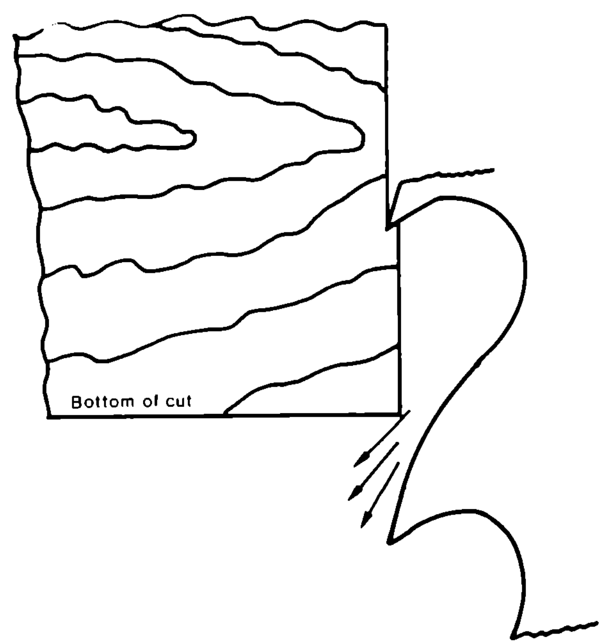


Figure 10. Tooth bite.

side clearance will be approximately 0.75 mm. The minimum bite per tooth should be greater than the side clearance. The bite per tooth is governed by the saw speed, tooth pitch and feed speed:

$$\text{bite per tooth} = \text{tooth pitch} \times \frac{\text{feed speed}}{\text{saw speed}}.$$

A typical saw speed in British sawmills is 2250 metres per minute. If the minimum bite per tooth is taken to be 1 mm then Table 2 gives the minimum feed speed for tooth pitches of 38, 45 and 50 mm.

Maximum feed speed

The majority of the sawdust generated has to be carried away in the gullet. Published experimental results indicate that the gullet can carry approximately 70% of the equivalent solid wood volume. The ratio of sawdust volume to solid wood volume varies between 3:1 and 6:1 (3:1 for green softwood to 6:1 for dry density timber) but the sawdust does not expand to its free volume until the tooth clears the timber. For a set feed speed and tooth pitch, the gullet size determines the maximum depth of cut which the saw can cope with (assuming the drive motor has adequate power). Table 3 gives the maximum depth of cut for the tooth pitch and minimum feed speed given in Table 2.

Either too low a feed speed or too high a feed speed can lead to sawing accuracy problems. Calculations should be carried out to ensure that feed speed, depth of cut, saw speed, tooth pitch and gullet capacity are correctly matched.

Table 2. Relationship between tooth pitch and minimum feed speed for a 1 mm bite

Tooth pitch (mm)	*Minimum feed speed for 1 mm bite (metres per minute)*
38	59
45	50
50	45

Table 3. Maximum depth of cut at minimum feed speed for a 1 mm bite

Tooth pitch (mm)	*Gullet area (mm^2)*	*Minimum feed speed for 1 mm bite (metres per minute)*	*Maximum depth of cut (mm)*
38	275	59	190
45	350	50	245
50	425	45	297

The influence of the timber on sawing accuracy

The importance of adequate kerf and side clearance when sawing dry British-grown Sitka spruce has been covered in a previous section. Investigations have been carried out to discover which aspects of timber or log quality significantly affect the accuracy with which British-grown spruce can be sawn. It was found that (i) dry timber, (ii) timber possessing a relatively low density, and (iii) timber from logs with poor form all tended to reduce the accuracy with which timber could be sawn by producing larger sawblade deflections. In particular it was noticed that dry timber and/or low density timber was sawn with a rougher or woollier surface finish. Large knots tended to make the sawblade deviate and in some cases damaged individual teeth.

Sitka spruce should be sawn green rather than dry. Better sawing accuracy will be achieved when sawing higher density material from logs of good form.

Check-list for accurate sawing

1. Set up a quality control system to monitor sawing accuracy and performance, based upon detailed sawn timber measurements taken regularly from each saw throughout each production shift (as outlined in the Appendix).
2. Aim for a 'within piece' standard deviation of less than 0.3 mm.
3. Aim to keep 'between piece' standard deviation less than 'within piece' standard deviation.

4. To minimise the overall sawing variation it is recommended that close attention be given to the following.
   - Adjustment of the setworks or sawguides, etc., to minimise the 'between piece' variation.
   - Careful and very uniform tensioning of the sawblade to match it to the characteristics of the saw pulleys.
   - Balancing of feed rate, depth of cut and tooth pitch; in particular the feed rate should be above that required for the minimum bite per tooth.
   - Selection of tooth shape to give a large capacity gullet with a curved bottom, as shown in Figure 8a.
   - Very careful attention paid to swaging and side dressing. The swage needs to be very even and not less than 0.75 mm per side on a primary breakdown machine. The swaging is required to produce a strong tooth tip to resist the damaging effects of the very hard dead knots which are found in spruce.
   - Timber should be sawn green rather than permitted to dry.
   - Careful and regular maintenance or replacement of sawguides is needed. In particular pressure guides based on the cartridge system which can be resurfaced and set up off the machine are a very worthwhile conversion.

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FURTHER READING

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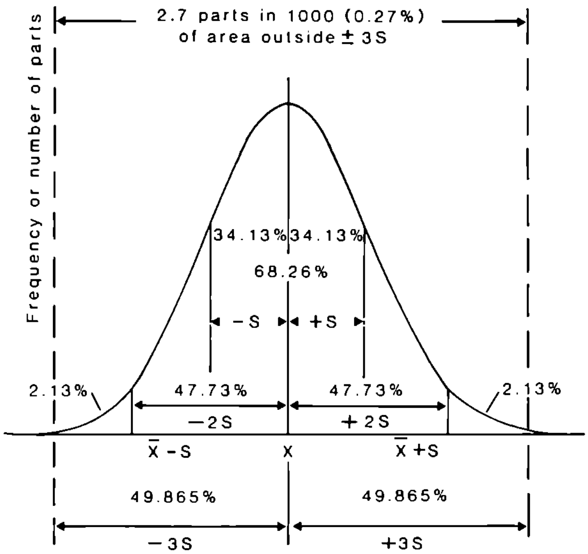
Appendix



± S includes 68.26% of total production

± $2S$ includes 95.46% of total production

± $3S$ includes 99.73% of total production

X = individual thickness reading

$\bar{X}$ = average or mean size

n = number of measurements within a board

N = number of boards in a test

S = sample standard deviation within a board

S_W = sample standard deviation within boards for a group

S_B = sample standard deviation between mean sizes

S_T = process sample standard deviation

The standard deviation is the most frequently used measure of the spread of a series of data.

Equations 1, 2, and 3 are arranged to give an estimate of the total process from a relatively small sample:

1. $$S = \sqrt{\frac{\Sigma (X - \bar{X})^2}{n-1}}$$

Standard deviation within a single board.

2. $$S_W = \sqrt{\frac{\Sigma S^2}{N}}$$

Standard deviation within boards for a group.

S_B = standard deviation between mean sizes.

Use equation 1 and let:

X = average or mean board size

$\bar{X}$ = overall average or grand mean size.

3. $$S_T = \sqrt{\frac{(N-1)\,n\,S_B^2 + N(n-1)\,S_W^2}{(Nn) - 1}}$$

Total standard deviation.

Example of calculations of standard deviation within pieces, between pieces and total or overall standard deviation

The calculations involve handling a considerable quantity of numbers or measurements and are best carried out on a programmable calculator or, preferably, a microcomputer. The basic formulae used are given in the previous section. This current section works through an example using ten sets of dimensions taken from 47 mm battens. In each case nine measurements were taken from each batten and recorded. Equation 1 in the previous section is the basic formula traditionally used to calculate the standard deviation of a set of measurements such as thickness or width of pieces of timber. The equation can be rearranged into a form more suited to programmable microcomputers:

$$S = \sqrt{\frac{\Sigma X - \frac{(\Sigma X)^2}{n}}{n-1}}$$

Batten 1

Thickness measurements	*Thickness squared*
48.35	2337.72
48.32	2334.82
47.17	2225.01
47.11	2219.35
48.00	2304.00
47.78	2282.93
47.42	2248.66
47.89	2293.45
47.30	2237.29
429.34 (ΣX)	20483.23 (ΣX^2)

Sum of thickness measurements divided by number of measurements = 429.34 ÷ 9 = 47.70 mm

SUMSQ = (sum of thickness measurements × sum of thickness measurements) ÷ number = (429.34 × 429.34) ÷ 9 = 20481.42

VARIANCE = (total of measurements × measurements – SUMSQ) ÷ (number of measurements – 1)
= (20483.23 – 20481.42) ÷ 8
= 0.23

STANDARD DEVIATION within this batten
Square Root of Variance = 0.48 mm

Batten 2

Thickness measurements	*Thickness squared*
49.04	2404.92
49.12	2412.77
48.67	2368.77
48.79	2380.46
48.76	2377.54
49.00	2401.00
48.26	2329.03
48.87	2388.28
48.40	2342.56
438.91	21405.33

Average thickness = 48.77 mm
SUMSQ = 21404.67, VARIANCE = 0.08
Standard deviation within this batten = 0.28 mm

Batten 3

Thickness measurements	*Thickness squared*
47.90	2294.41
48.23	2326.13
48.49	2351.28
47.93	2297.28
48.35	2337.72
48.49	2351.28
48.68	2369.74
48.11	2314.57
48.40	2342.56
434.58	20984.99

Average thickness = 48.29 mm
SUMSQ = 20984.42, VARIANCE = 0.07
Standard deviation within this batten = 0.26 mm

Batten 4

Thickness measurements	*Thickness squared*
436.62	21183.88

Average thickness = 48.51 mm
SUMSQ = 21181.89, VARIANCE = 0.25
Standard deviation within this batten
= 0.50 mm

Batten 5

Thickness measurements	*Thickness squared*
426.46	20209.28

Average thickness = 47.38 mm
SUMSQ = 20207.57, VARIANCE = 0.21
Standard deviation within this batten
= 0.46 mm

Batten 6

Thickness measurements	*Thickness squared*
438.55	21373.04

Average thickness = 48.73 mm
SUMSQ = 21369.57, VARIANCE = 0.43
Standard deviation within this batten
= 0.66 mm

Batten 7

Thickness measurements	*Thickness squared*
437.75	21295.11

Average thickness = 48.64 mm
SUMSQ = 21291.67, VARIANCE = 0.43
Standard deviation within this batten
= 0.66 mm

Batten 8

Thickness measurements	*Thickness squared*
435.28	21052.66

Average thickness = 48.36 mm
SUMSQ = 211052.08, VARIANCE = 0.07
Standard deviation within this batten
= 0.26 mm

Batten 9

Thickness measurements	*Thickness squared*
434.33	20960.64

Average thickness = 48.26 mm
SUMSQ = 20960.28, VARIANCE = 0.04
Standard deviation within this batten
= 0.20 mm

Batten 10

Thickness measurements	*Thickness squared*
425.26	20095.83

Average thickness = 47.25 mm
SUMSQ = 20094.01, VARIANCE = 0.23
Standard deviation within this batten
= 0.48 mm

Within piece standard deviation – S_W

= SQUARE ROOT of (SUM of individual VARIANCES) ÷ number of pieces
= SQUARE ROOT (0.23 + 0.08 + 0.07 + 0.25 + 0.21 + 0.43 + 0.43 + 0.07 + 0.04 + 0.23) ÷ 10
= SQUARE ROOT ((2.04) ÷ 10) = 0.45 mm

Between piece standard deviation

Overall average batten thickness = (47.7 + 48.77 + 48.29 etc. + 47.25) ÷ number of battens (4819) ÷ 10 = 48.19 mm

Sum of average batten thicknesses squared = (47.7 × 47.7 + 48.29 × 48.29 etc. + 47.25 × 47.25) = 23225.29

(Sum of batten thicknesses) × (Sum of batten thicknesses) = 232227
divided by number of battens = 23222.7

Variance between battens = (23225.29 – 23222.7) ÷ number of battens – 1 = 0.287

Standard deviation between battens = square root (0.287) = 0.54 mm

Overall standard deviation

This is given by Equation 3 in the list of formulae on page 13.

$$S_T = \sqrt{\frac{[(10-1) \times 9 \times 0.54 \times 0.54] + [10 \times (9-1) \times 0.45 \times 0.45]}{(10 \times 9) - 1}}$$

$$= \sqrt{\frac{[9 \times 9 \times 0.292] + [80 \times 0.2025]}{89}}$$

$$= 0.67 \text{ mm}$$

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