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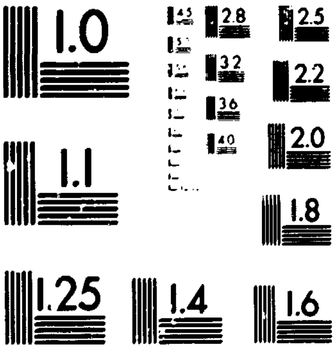

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RESEARCH AND DEVELOPMENT FOR THE UTILIZATION OF RUBBERWOOD AND COCONUT WOOD

DP/SRL/79/053

SRI LANKA

Technical report: Structural Fingerjointing of Timber*

Prepared for the Government of Sri Lanka
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of C. R. Francis, Timber Engineer

United Nations Industrial Development Organization
Vienna

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CONTENTS

1. INTRODUCTION

This report has been prepared to assist managerial level staff in the woodworking industry to understand the subject of fingerjointing. A fingerjointing operation may range from a small machine in one corner of a factory up to a complete plant devoted to nothing else. Despite this range in size, the fundamental considerations remain the same. Good (or bad) fingerjoints can be made just as well on small slow machines as on large automated ones.

Many countries have codes of practice which may differ in their requirements from the recommendations contained here. This applies particularly to the field of quality control and may also apply to permitted end uses for particular finger profiles. In this case the local code requirements must take precedence over any recommendations contained here.

Although glue is a vital part of fingerjointing, its selection, application and curing is barely touched on since this subject has been covered in detail in the same expert's report on the manufacture of glue laminated timber.

2. FINGERJOINTING

Joining wood end to end has always been a difficult problem. Generally, glued joints on end grain have very little strength. Some laboratory work has produced fairly high strength end-grain joints using epoxy adhesives but the techniques are not suitable for production work and so far remain a laboratory curiosity.

For structural work, high strength end joints can be made by gluing scarfed ends together - see Fig. 1.

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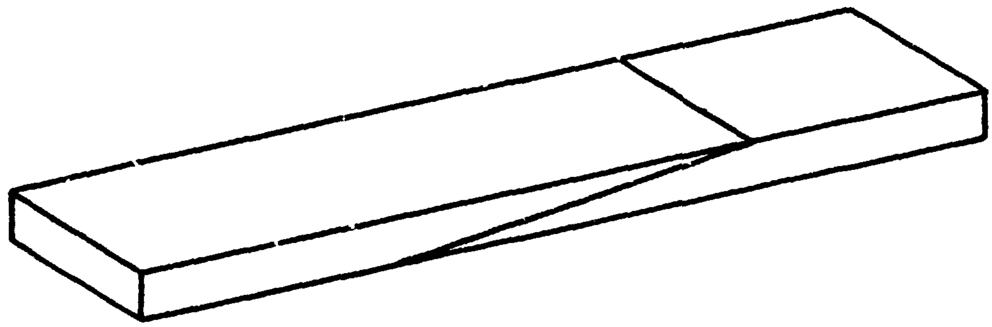


Fig. 1. Plain scarf joint

Flat cut scarf joints cut at a slope of 1 in 10 or 1 in 12 can develop over 80 per cent of the strength of unjointed wood. Scarf joints suffer from various limitations:

They are very wasteful of timber;
They are difficult to machine accurately;
They are difficult to hold in alignment while the glue curses.

Various techniques have been tried to overcome one or more of the above limitations, but none has been really successful.

A scarf joint derives its strength from the large area of near side-grain which forms the glueing surface.

If a scarf joint is folded back on itself several times, it becomes a finger joint - see Fig. 2.

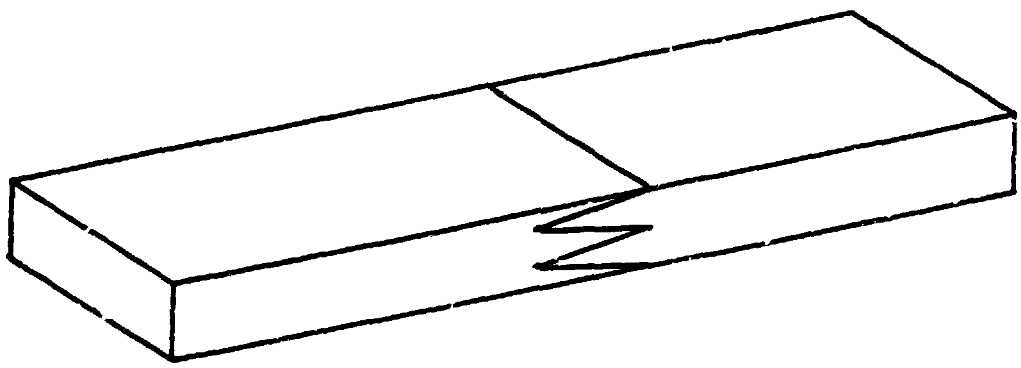


Fig. 2. Horizontal fingerjoint

A finger joint maintains the flat slope of grain of the scarf joint and hence its high strength, but it is much shorter and less wasteful of timber and is also selfaligning. If it is pushed together longitudinally, lateral pressures are developed which provide glueing pressure. Finger joints may be cut parallel to the wide face of the timber as shown in Fig. 2. This is called a "horizontal" finger joint. They may also be cut perpendicular to the wide face when they are known as "vertical" finger joint - see Fig. 3. Both types have advantages and disadvantages.

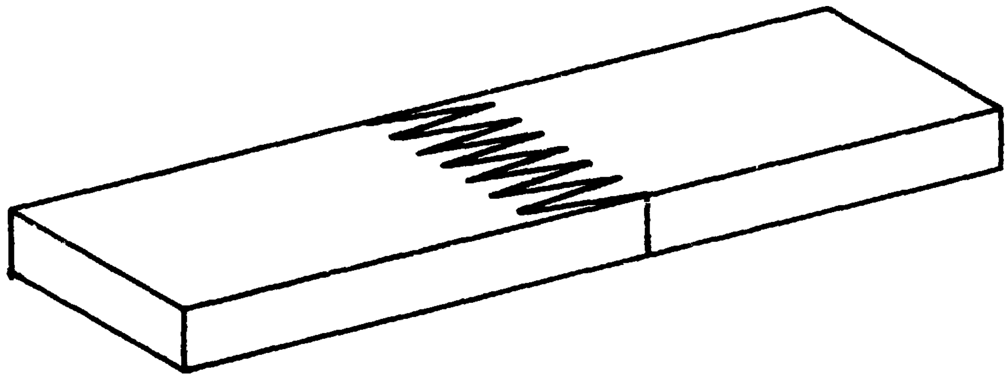


Fig. 3. Vertical fingerjoinc

3. FINGERJOINT PROFILES

The lengths of fingerjoints in commercial use range from about 100 mm down to 4 mm. The larger fingers are generally cut with banks of angled saws or built up cutters, whereas the shorter fingers are cut with expensive solid profile cutters. Finger profiles and cutters are shown in Fig. 4. The large fingers require external clamping while the glue cures in order to have adequate glueing pressure without splits developing, while the short fingers need only to be pushed together with a controlled force. Friction then holds them together while the glue cures.

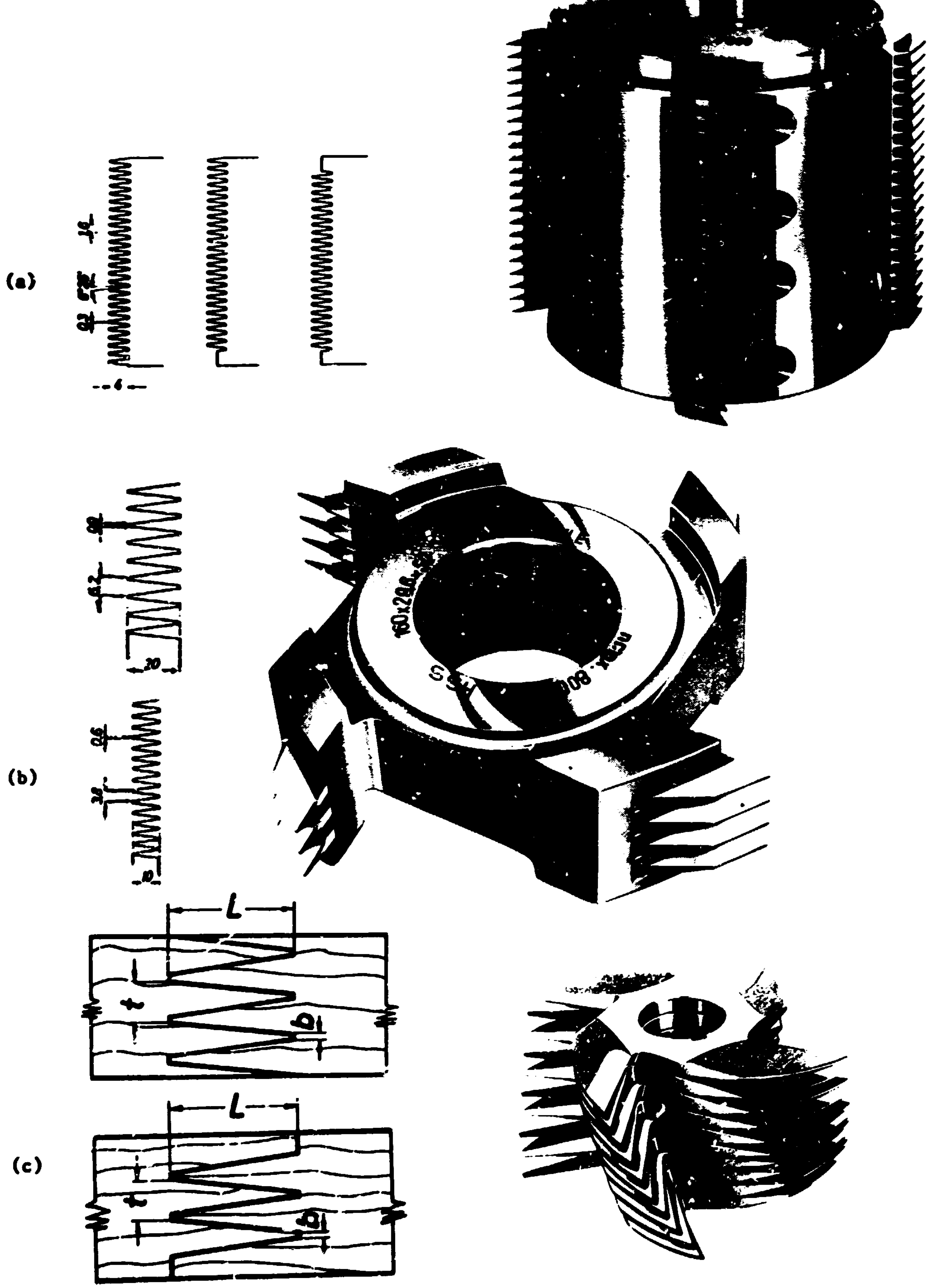


Fig. 4. (a) Profiled knife in cutterhead, 4 mm (b) Solid cutter 10-20 mm (c) Individual fly cutter

The smallest fingerjoints in commercial use have a length of 4 mm. These do not develop very high strengths - only about 40 per cent of unjointed wood strength. This is partly because the tip width of 0.3 mm is 19 per cent of the transverse pitch of 1.6 mm. Consequently, 38 per cent of the cross section is effectively end grain. There also appears to be an effect that, when the finger length becomes of the same order of size as the length of the wood fibres, strength falls off.

Longer fingers of 10 mm, 15 mm and 20 mm are now commonly used for structural purposes. 10 mm fingers regularly develop minimum joint strengths of 60 per cent of unjointed wood and longer fingers with flatter slopes up to 80 per cent. The apparent increase of strength with finger length is not due directly to the length of the fingers. Rather it is due to the decreasing proportion of end grain on practical production cutters and the flatter flank slopes associated with longer teeth. Experiments indicate that 10 mm long fingerjoints can develop equally high strength, but the necessary cutters are too fragile for commercial use.

4. STRUCTURAL AND NON-STRUCTURAL FINGERJOINTS

A very large proportion of timber which is finger-jointed has very little stress applied to it. Typical end uses with low stress include mouldings, weather-boards, fascia, joinery stock and floor-boards. The major strength requirement for these commodities is merely that the joints shall withstand handling and fixing loads. These are generally the severest load to which they will ever be subjected. The requirements for fingerjoints for these purposes are mainly those of appearance. Tightly fitting joints and neat appearance with no break out caused by machining the fingers are important. Joint profiles used for these purposes generally have fairly blunt fingers, frequently with a wider abutting section where the joint will be exposed to view as shown in Fig. 4 (a) and 4 (c). Glues used for these materials are frequently non-weather proof types such as PVA or urea formaldehyde.

Being transparent, these glues form a nearly invisible glue line. Finishing timbers fingerjointed with transparent glues and tightly fitting exposed joint lines are as acceptable as natural unjointed timbers for many end uses.

Structural fingerjoints are required to carry an assigned stress. End uses of structurally fingerjointed timber include glulam stock, timber for trussed rafter manufacture and light framing construction.

The principal requirement for structural fingerjoints is a known minimum strength, but appearance will also frequently be important, and break-out introduces abrupt narrowing of the section which causes stress concentration.

The term "structural" does not necessarily mean "high strength" but rather "guaranteed minimum strength". Even though joints are rated in terms of the ratio of joint strength to that of unjointed clear wood, in practice very little structural timber is ever deliberately stressed up to the clear wood strength level. Structural timber is graded and in each grade various defects are permitted - - knots of various sizes and types, sloping grain etc. Quite small defects have a marked effect on strength, and the top commercial grades designated by such terms as "select structural" are generally only about 65 per cent or 70 per cent strength ratio, with "structural" and "framing" or "building" grades having strength ratios in the 40 per cent to 50 per cent range. Provided that a fingerjoint is at least as strong as the weakest section permitted by the grading rule concerned, it should be acceptable for structural timber in that grade.

In practice, reasonably well made fingerjoints of a suitable profile regularly reach average strengths of 60 per cent to 80 per cent of clear wood strength which is compatible with the higher structural grades. The problem with structural fingerjointing therefore, is not so much in reaching a given strength level, but rather in maintaining it. This can only be done by appropriate quality control procedures which involve physical testing.

Quality control, by its nature, implies the production of occasional reject batches. The question always arises what to do with the rejects?

In factories producing a variety of products which includes non-structural items, reject structural fingerjointed stock may be put into these provided that glue colour and finger profile are acceptable. In factories where only structural items are produced the choice is more difficult. In truss plants, there can be no question of using rejected timber and the only options available are to dispose of the timber to a known non-structural use, or to cut out the joints and re-fingerjoint the timber.

In glulam plants it may be possible to absorb reject finger-joints in areas and components of low stress e.g. near the neutral axis of beams, in heavy decking, or in diaphrams in bridges. A decision as to whether this is permissable should be made by a responsible engineer. Such zones are commonly used to absorb low grade timber[1/] and the expert sees no reason why suspect fingerjoints should not be regarded simply as another grading effect.

5. STRENGTH OF FINGERJOINTS

The strength of a fingerjoint depends on a number of factors. These are:

1. Slope of finger flanks;
2. Width of blunt finger tip;
3. Adequacy of glueing pressure;
4. Length of fingers relative to length of wood fibres.

These will be examined in detail.

The effect of slope of grain on scarf joints has already been explained. The table on page 8 shows accepted efficiencies of scarf joints at various slopes.

[1/] See DP/ID/SER.A/322, Vienna 1981, "Glulam bridges for developing countries - UNIDO".

Efficiencies of Scarf Joints

Slope of scarf	Efficiency as % of unjointed wood
Butt joint square	0
1 in 5	65
1 in 8	80
1 in 10	85
1 in 12	90

The same factors apply to the strength of fingerjoints. Consequently, high strength fingerjoints must have only a slight taper, while joints which do not require so much strength may have more steeply sloping flanks.

While there is no major difference in the actual machining of either type, the cutters for more steeply sloping fingerjoints are easier to manufacture, hence cheaper and also easier to maintain.

It is not possible to machine end grain timber to an absolutely sharp point. Such a feather edge would be very fragile and would break off more or less unevenly. Also, cutters brought to a sharp point are fragile and become bluntened after only a few operations. Consequently, all fingerjoints have more or less blunt tips.

Blunt tips expose end grain, which has no strength when glued. Also, the abrupt transitions from side to end grain induce zones of stress concentration when the joint is under load, and hence zones where failure will commence. In some designs of cutters the point (and corresponding root) are rounded in order to reduce this stress concentration. Even so, the end grain effect remains.

Blunt tipped joints are easier to machine and the cutters are easier to maintain than those for fine tipped joints. Consequently, blunt tipped fingerjoints are widely used where high strength is not important while fine tips are reserved for structural work.

6. GLUEING PRESSURE

Strong glue joints require adequate pressure to be maintained across the glue line until the glue cures. This pressure is generally supplied by pushing the fingerjoints together under a controlled force, when the wedging action of the tapered fingers supplies the pressure.

Consider a single finger with flank angle θ, and thickness 2t of unit width, as shown in Fig. 5.

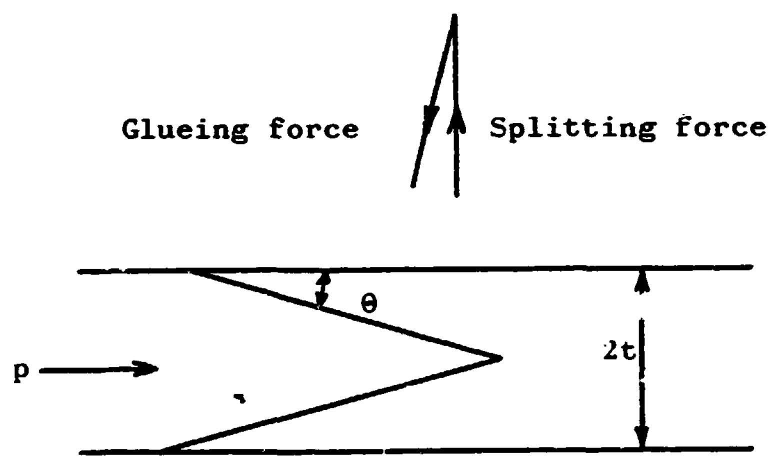


Fig. 5. Single ideal fingerjoint

Then on one face of the finger, and neglecting friction

End force $= pt$

Force perpendicular to glueline $= \dfrac{pt}{\sin \theta}$

Force perpendicular to grain, i.e., splitting force $= \dfrac{pt}{\tan \theta}$

Area of glue face $= \dfrac{t}{\sin \theta}$

Glueing pressure $= \dfrac{pt}{\sin \theta} \times \dfrac{\sin \theta}{t}$

$= p$

Two interesting facts emerge from this analysis. The glueing pressure equals the end pressure. (Note that we are distinguishing carefully between forces and pressures). Therefore, if we require a glueing pressure of 1000 kPa we must push the joint together with a force of 1000 kPa times the cross sectional area of the timber. In practice, the end force must be a little greater, to overcome friction.

The cleaving or splitting force on the root of a finger is proportional to the thickness of each finger. Therefore, fine pitch fingers are much less prone to splitting than coarse pitch fingers.

7. BREAK-OUT (TEAR OUT, SPELCHING)

Fingerjoints are generally cut by the "up-milling" process. By this is meant that the rotating motion of the cutting teeth is opposed to the direction of feed - see Fig. 6.

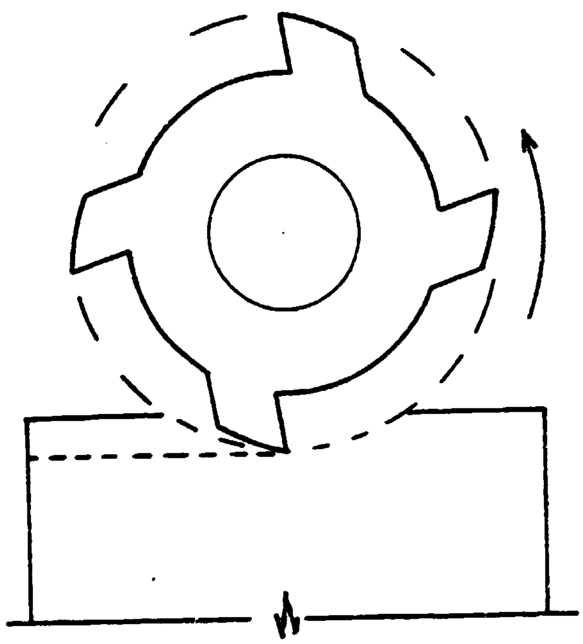


Fig. 6. Up-milling cutting

A clean cut results through most of the wood since the fibres are supported by the uncut wood behind them. However, when the cutters emerge from the wood, the fibres tend to split along the grain rather than be cut and the exit is ragged. This is known as "Break-out", "Tear-out" or "Spelching", depending on local usage.

In some designs of finger-jointing machines, the proportion, but not necessarily the severity of break-out is reduced by clamping several pieces of wood together and machining across the whole packet. In this case only the last piece of wood in the packet is subject to break-out, but severity in this piece is not reduced.

In order to minimise break-out, many machines incorporate a back-up piece of hard wood or plastic. In the expert's experience, none of these seem to last very long, possibly since fitting and machining these was regarded as something of an after-thought. Consequently after a relatively short period the fingers on the plastic or wooden pieces were largely worn away.

In one case which came to the expert's attention break-out appeared to have been successfully overcome. Solid aluminium bar was used for back-up pieces, and this was fixed in place for machining by the fingerjointing head, and shimmed as far forward as possible. The normal feed was replaced by a manual screw feed and arrangements made to flood the cutting area with kerosene. For this a 20 litre can with hose and control valve was suspended above the cutting area. The cut was made under a flood of kerosene at a slow feed speed, only one pass. After machining, the faces of the fingers in the aluminium and the area around were covered in bitumen, then the other surfaces were degreased, pickled and anodised to provide a hard surface. These back-up combs were reported to have lasted several months and to have handsomely repaid their high initial cost ir eliminating rejects due to break-out.

Consistent heavy break-out is a sign that cutters need re-sharpening.

8. CUTTERS AND CUTTER MAINTENANCE

Fingerjoints are machined by passing profiled cutters across the end grain of the timber. Cutters are of various types. The principal types in order of increasing finger lengths are:

1. Profiled knife, set in cutter head;
2. Solid with integral teeth;
3. Cutter head with individual adjustable teeth; and
4. Individual fly-cutter.

These are shown in Fig. 4 together with typical tooth profiles produced by each type.

Cutters are valuable fragile tools. They must be handled carefully. A wooden box with a central spigot should be made for each set of cutters and they should always be stored and transported in this box.

Cutters of types 2 and 4 should be kept in sets. In many cases cutters will have a serial number and sets should be made up of consecutive numbers. For easy identification, the body of each set may be painted a different colour. Thus, the "red" set may be in the machine, the "green" set being sharped and the "blue" set spare. Similarly, the numbers 1, 2, 3, etc. should be painted on each cutter, and the set always put into the machine and sharpened in the same order.

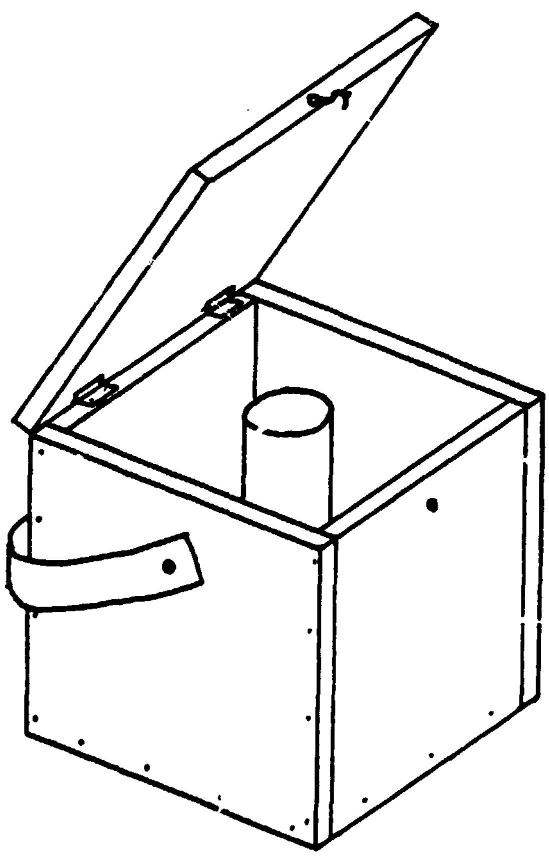


Fig. 7. Cutter storage box

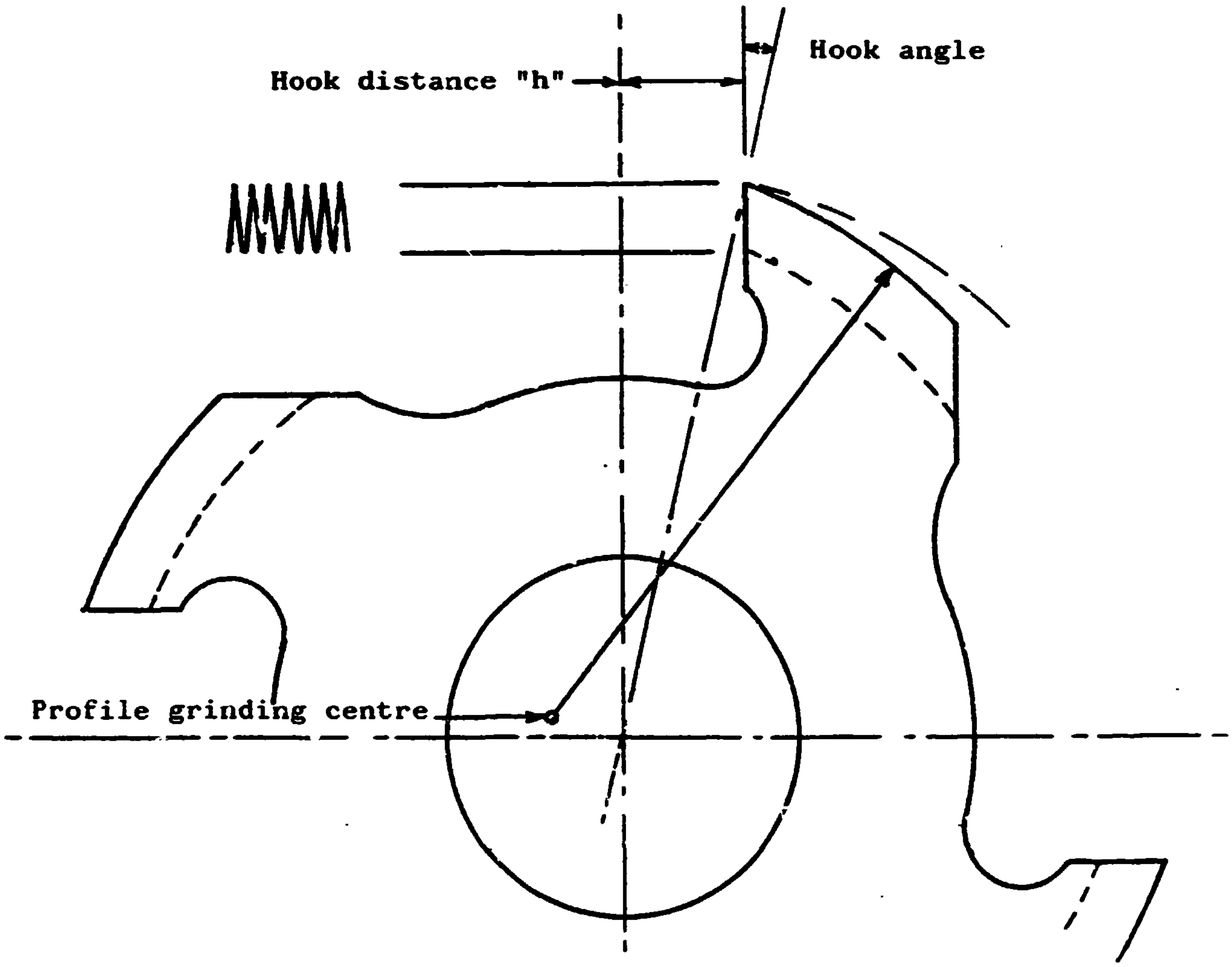


Fig. 8. Cutter geometry

Fingerjointing cutters are carefully designed to cut accurate profiles. The front face has a hook angle of about 15°. Top and side relief are provided by grinding the finger profile from a different centre than the arbour centre. This is shown in Fig. 8. Provided the hook angle is maintained constant the finger length, and flank angle also remain constant and accurately mating fingers will result. If the hook angle is changed, then different length teeth will result. This is not of great importance where the fingers at both ends of the wood are machined by the same set of cutters, but it becomes vital where the different sets of cutters machine the two ends. The reason for the change in finger length is shown in Fig. 9.

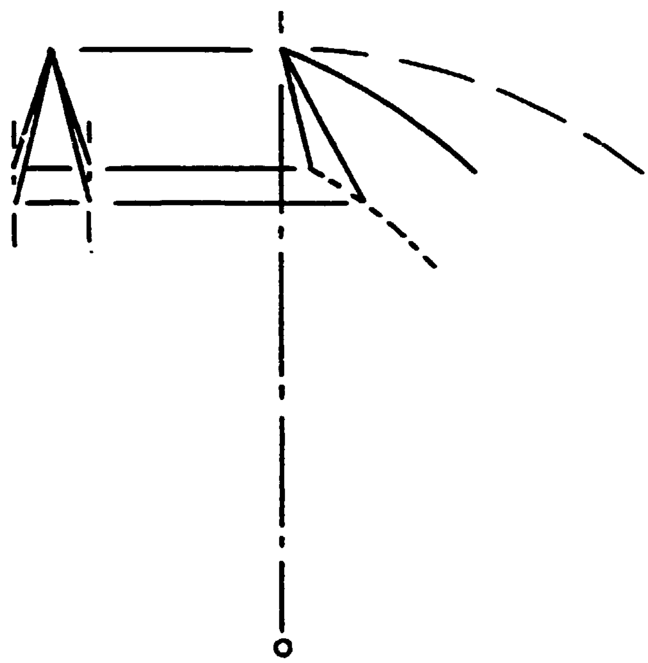
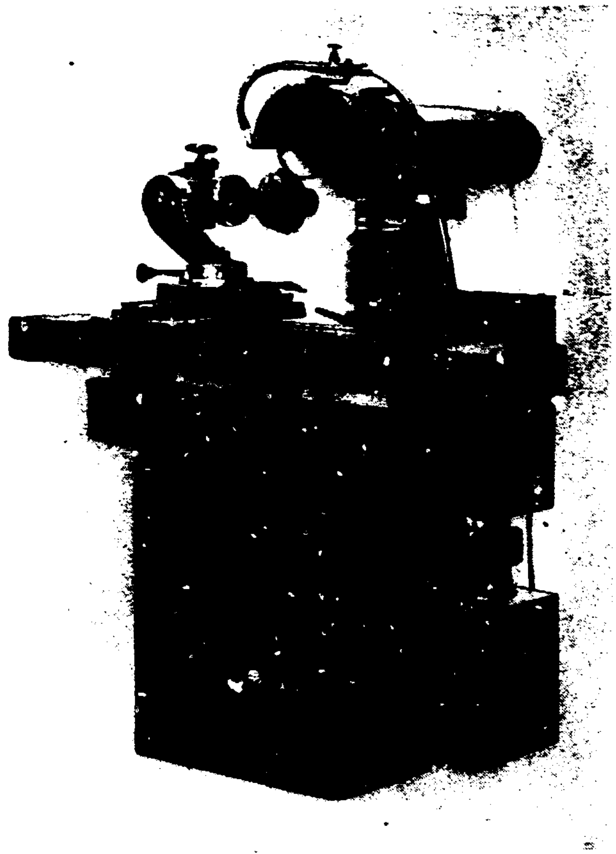


Fig. 9. Effect of variation in hook angle

The most commonly used sharpening machine for fingerjointing cutters is a universal tool grinding carrying a "saucer" or "dish" wheel. A typical machine is shown in Fig. 10. This should be set up accurately level on a heavy concrete foundation and provided with a bright light.

Since there are minor differences between different machines, no comprehensive directions can be given and the following instructions must be read in conjunction with the detailed instructions for the particular machine in use, and by reference to the machine itself.

Various accessories are required for cutter sharpening. The cutters themselves are mounted on a precision ground arbour which must have a lengthwise clamping device. Preferably a solid full-diameter one with make-up bushes for improved precision.



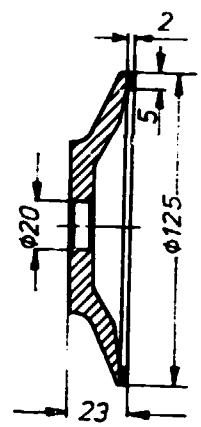


Fig. 10. (a) Universal grinder (b) Dish wheel

The arbour is held either at one end by a workhead or at both ends between centres. The workhead is more convenient, but an held between centres is more precise, particularly for long banks of cutters.

The arbour must be equipped with a dividing plate with a slow motion adjusting screw, working in a rotational sense around the arbour's axis.

A dial gauge is required to check parallelism of the set up. This should read to 0.025 mm (0.001 in) and should be equipped with both ball and flat anvils. It should have the usual fixing rods and clamps and magnetic base.

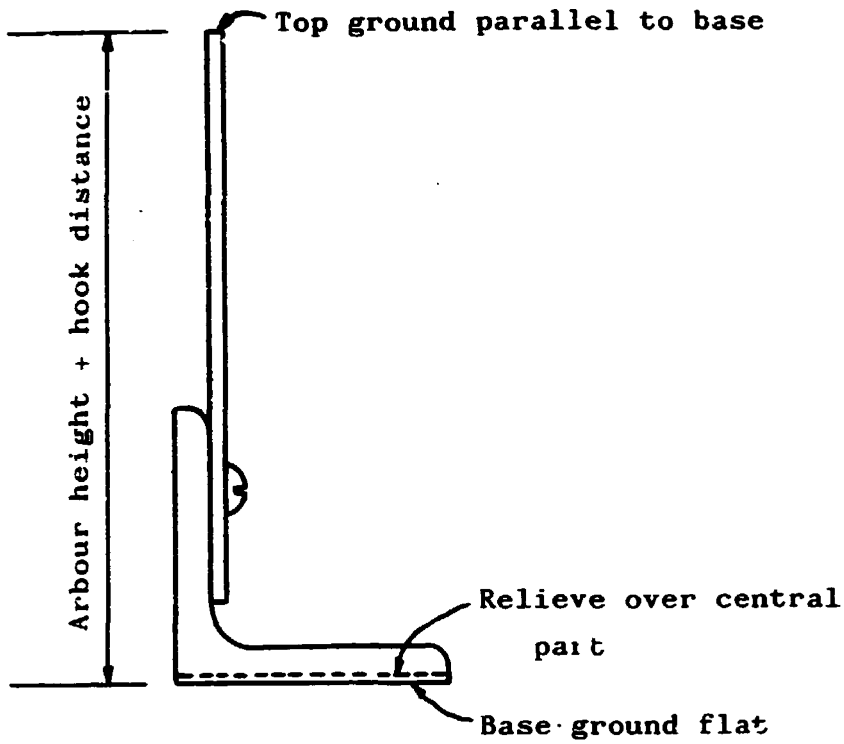


Fig. 11. Setting bar

A setting bar is required to set the faces of the cutters in line parallel to the axis of the arbour. This consists of a plate which has one edge a distance above the table of the centre height plus the hook distance. This edge is accurately parallel to the bed of the grinder. It rests on an angle base with precision ground feet which contact the table. It may be available as an accessory with some grinders. If not, it can be made from a piece of steel angle and a piece of saw plate as shown in Fig. 11. The base and the top edge may be ground in the universal grinder using an ordinary flat face carborundum wheel.

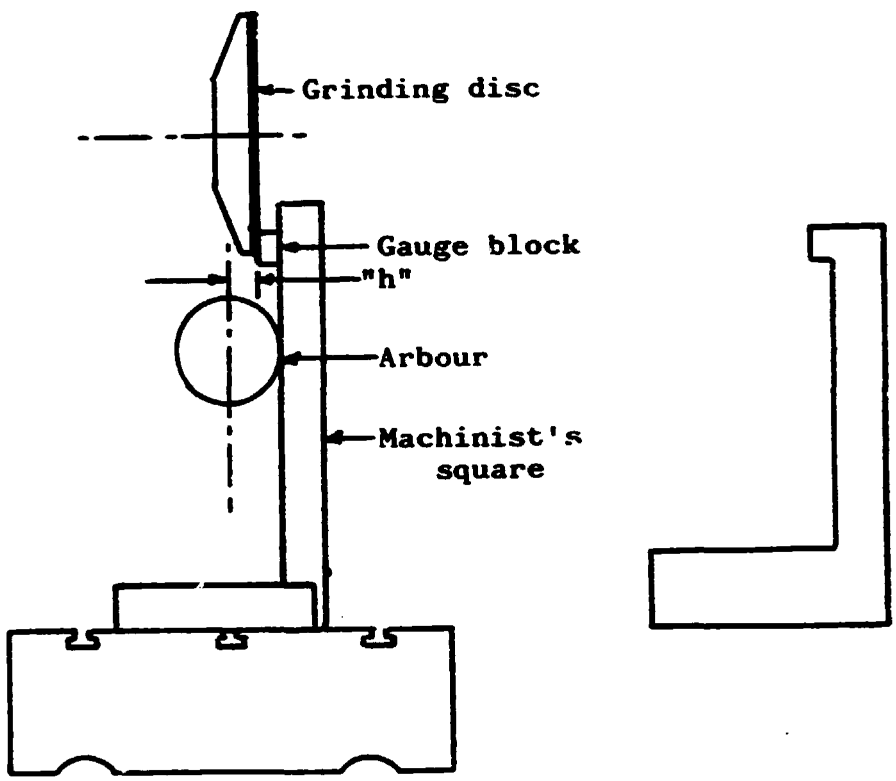


Fig. 12. (a) Setting of dish wheel (b) Purpose made gauge

A distance gauge and a precision try-square are required for setting the dish wheel relative to the arbour. The distance gauge should have a width equal to the arbour radius minus the hook distance, as shown in Fig. 12 (a). A competent tool maker could make a one-piece gauge, as indicated in Fig. 12 (b) from a piece of saw plate. Again the necessary grinding can be done in the universal grinder itself.

A 5 x or 10 x jewellers loupe is required for examining the condition of the teeth.

9. GRINDING WHEELS

The profile of a typical dish wheel is shown in Fig. 10. For mini-fingerjoint cutters it is essential that only boron-nitride ("Borazon") wheels are used, with liquid or mist coolant constantly applied. For tungsten carbide tipped (TCT) cutters, only diamond wheels can be used.

The teeth of fine cutters are subjected to high stresses when cutting. Carborundum or similar wheels make minute scratches on the face of the teeth, particularly if used dry. These scratches act as stress concentration points which in turn lead to the fracture of the tooth points when cutting. Loss of a tooth point will ruin a whole, expensive cutter. Experience has shown that cooled Borazon wheels greatly reduce the incidence of tooth breakage and quickly repay the extra cost of the wheels.

10. SETTING UP FOR SHARPENING

Setting up is performed in the following steps. After each stage, the accuracy of setting up should be checked with the dial gauge, using the ball anvil for flat surfaces and the flat anvil for points. Retract the dial gauge from the work before traversing the table. This will avoid bending its spindle.

1. The arbour is mounted and checked for parallel to the table traverse both horizontally and vertically;
2. The cutters are placed on the arbour in order and adjusted so that the faces are in line;
3. The setting bar is placed on the table and the faces of all the cutters are rested on it. The vertical face of the bank of cutters is then checked for parallel, the cutters tightened up and re-checked;
4. The table is then advanced until the distance gauge, referenced to the arbour, touches the grinding disc as shown in Fig. 12.

   (Note: on some machines it may be necessary to perform this step before step No. 2. In this case, the reading of the micrometer thimble on the feed screw should be noted at the correct setting. The table is then backed off to allow the cutters to be mounted. After step 3, the table is advanced to the previously noted reading).

5. The coolant is turned on, the grinding disc is started, a trial cut is taken cautiously. If setting up has been carried out correctly, the grinding disc should just "kiss" the face of the cutters. A bank of cutters set up for grinding is shown in Fig. 13.

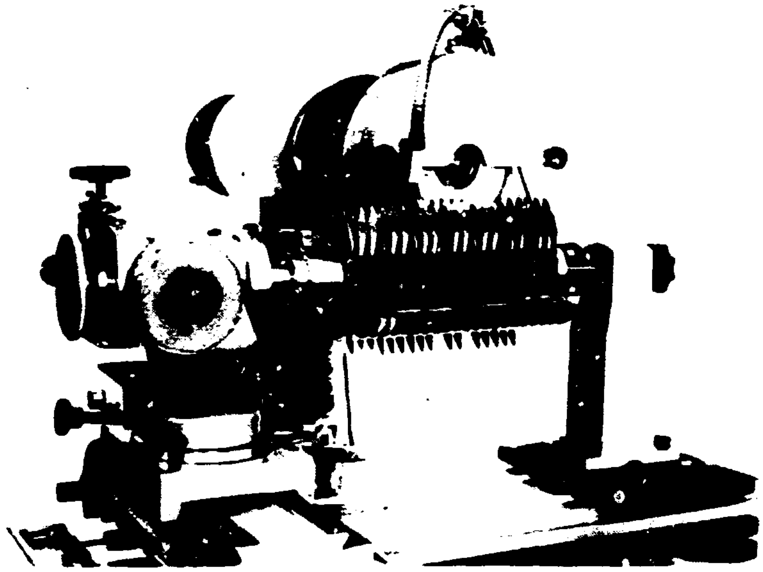


Fig. 13. Bank of cutters set up for grinding

6. When the set up is satisfactory, the cutters are rotated into the grinding disc by about 0.0015 in and the dividing plate is locked into position. All faces may now be ground in succession. Note that the cutters should not be ground by feeding the table into the grinding disc since this will result in a change in hook angle.

11. GRINDING

Before starting grinding, the face of the grinding disc should be checked to see that it is running true. The contents of the coolant reservoir should be checked and, if necessary, topped up. After grinding has been completed, on each face, the condition of the teeth should be checked with the loupe. When all signs of bluntening have been ground off, the bank of cutters is sharpened. Before removing the cutters from the arbour they should be checked for uniformity of diameter using the dial gauge fitted with a flat anvil.

When grinding is completed, the cutters should be wiped free of coolant and grinding dust and immediately replaced in their box.

12. FAULTS IN FINGERJOINTING

Various faults can occur in the fingerjointing process which result in reduced strength. These are detailed below.

1. Incorrectly ground cutters: Cutters must be ground exactly parallel to the axis and at the correct hook angle to give correctly shaped fingers. This requires skilled setting up of the grinder and careful measurement of individual cutter blocks to ensure uniformity over the whole axial length of a set of cutter blocks, other wise incorrect mating will occur - see Fig. 14.

(a) Correct length and angle (b) Incorrect length and angle

Fig. 14. Effect of correctly and incorrectly ground cutters

2. Machining not square and full depth: If the ends of the pieces to be machined are not pushed right up to the stop before machining starts, or if they slip in the clamps either away from the cutters or in a twisting fashion, incompletely machined fingers will result. In either case, a correctly fitted joint cannot be made.

3. Incomplete glueing: Single sided glueing can only be achieved satisfactorily by profiled rollers or combs and even with these it is very easy for a patch inside the joint to be missed. When hand glue application with brushes is used, it is difficult to ensure the placing of glue at the roots of the fingers and double glueing of all finger tips to half way down the fingers is the only sure way to guarantee uniform glue application to all surfaces of the mated joint.

4. Incorrect assembly and pressing: After machining and application of glue, the joints must be assembled. If machining and assembly are done correctly, there should be no offsets or steps in the resulting joints. Frequently pieces of different dimensions are fingerjointed. This may result from different sources of planed timber or from fingerjointing sawn but unplaned timber. In this case, obviously there will be a slight step at the joint amounting to the difference in size between the original pieces, but the reference face and edge should be in the same planes. This requires that the leading and trailing fingers should be offset in the machining process by half a pitch - see Fig. 15.

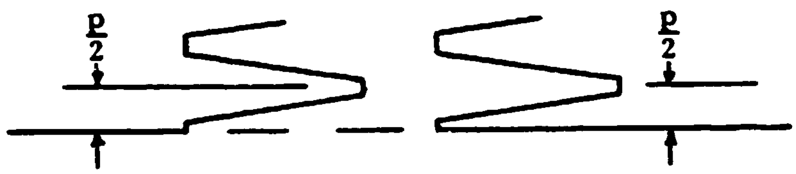


Fig. 15. Correctly offset fingers

A consistent offset at this reference face or edge should be eliminated by adjusting the fingerjointing machine.

Care must also be taken that the reference surfaces of the pieces are maintained in position and are not reversed. This is not a problem in large fully automatic machines, but in small hand assembled units it may be a problem to discipline oeprators to always perform the same motions. A possible solution, if sawing accuracy is good enough, is to plane to dimension on one face and one edge only. These planed surfaces then form the reference surfaces for all subsequent operations. The disadvantage with this is that it makes grading more difficult on the sawn faces.

Incorrect assembly pressure will also result in weak joints. Excessive end pressure may result in starved joints and even in compression failures across the roots of the fingers in weaker low density timber. Insufficient pressure, on the other hand, will not develop maximum strength.

The end pressure should be about 20 per cent to 50 per cent greater than the lateral pressure used in laminating the same species, provided that this can be achieved without excessive splitting at the bases of the fingers and without excessive squeeze-out, leading to starved joints.

If any of the above occur, there are various options:

1. Reduce the end pressure until splitting is reduced to acceptable levels (about 1 split in the outermost finger base of one in 10 joints). This must not lower the joint strength below acceptable levels, or reduce the proportion of wood failure in test joints.
2. Change the finger profile to one with a fine pitch.
3. If starved joints are a problem, change the glue formulation to a more viscous one, or increase the assembly time.

13. QUALITY CONTROL OF STRUCTURAL FINGERJOINTS

The quality control procedure of structural fingerjoints consists of testing sample joints to failure on a regular basis. The production batch represented by the sample is accepted or rejected on the basis of the strength of the sample joint and its failure characteristics.

The test equipment can be quite simple. A one-ton hydraulic jack fitted with a pressure gauge is used to load a sample over a 750 mm span in three-point bending. With some practice, a fairly uniform rate of application of load can be made and the pressure gauge canbe read quite accurately "on the fly". A photograph of one typical arrangement is shown in Fig. 16. From the sample dimension and the ultimate load the modulus of rupture at failure is calculated.

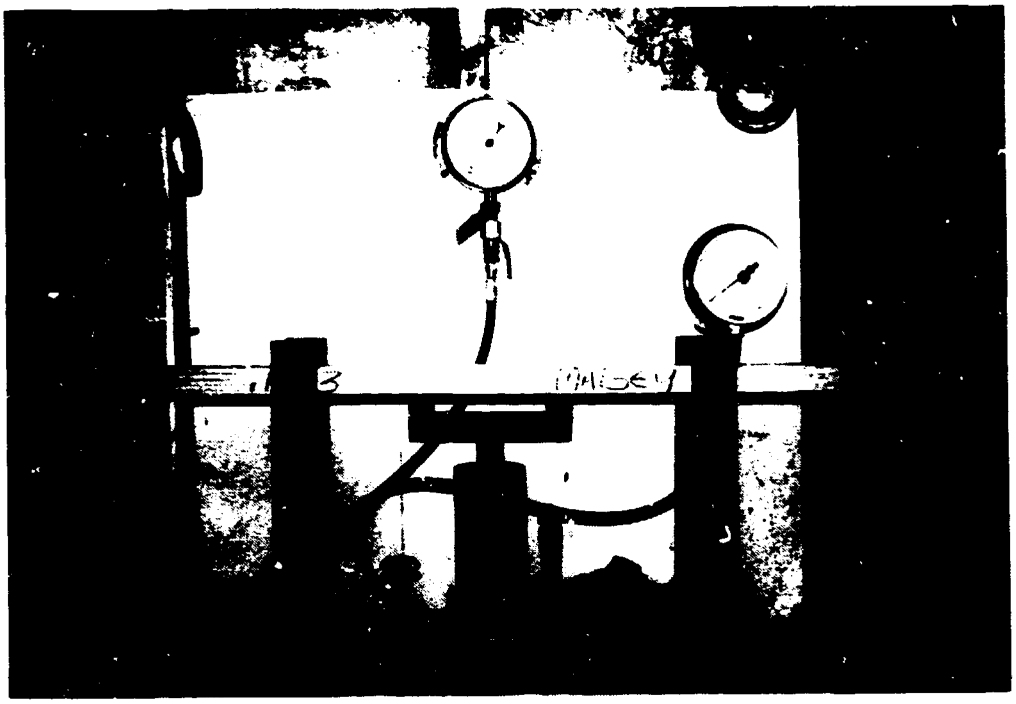


Fig. 16. Typical fingerjoint test equipment

Some codes require testing to be done in tension. This is generally too difficult and expensive for factory use, even though it may be theoretically more correct. The difficulty and expense militate against frequent testing, which is the essence of good quality control. Another requirement found in some codes is that bending tests should be in four point loading, as is done in laboratory tests to determine timber strength. The expert considers this unnecessary, since failure is required only in the short length of the fingerjoint.

The expert recommends the following as a basis for a suitable quality control system, based on the recommendations of the American Institute of Timber Construction.

Frequency of Sampling

One sample per sampling period. A sampling period is an uninterrupted period of work during which the same type of glue, the same species and treatment specification are being jointed, and the same cutters are in use. Thus a normal day shift broken by morning tea, lunch and afternoon tea would comprise four uninterrupted periods of work. Four samples would therefore, be tested every day. These breaks are also good times for changing cutters, both to minimise the number of tests and to maximise productive time.

St. ength

Three strength qualifications are required, expressed in terms of the maximum allowable strength in bending f_b of the timber, under normal conditions of load and dry use.

1. The average ultimate stress shall be at least 3.15 times f_b.
2. 95 per cent of the test value shall exceed 2.3625 f_b.
3. All of the test values shall exceed 1.8 times f_b.

A moving average over the last ten specimens tested is used for criteria 1 and 2. Values for these criteria in terms of the Australian stress grade system are given in Table 2 below.

Wood failure

Examination of the broken surfaces should show 70 per cent of wood failure. In interpreting whether failure has occured in wood or in the glue line, a uniform layer of wood fibres adhering to the glue shall be taken as wood failure even though the glue may be visible through the fibres.

Table 2

Stress Grade	F_b (kPa)	$3.15F_b$	$2.3625\ F_b$	$1.8\ F_b$
F4	4.3	13.55	10.16	7.74
F5	5.5	17.33	13.00	9.90
F7	6.9	21.74	16.3	12.42
F8	8.6	27.09	20.32	15.48
F11	11.0	34.65	25.99	19.80
F14	14.0	44.10	33.08	25.20
F17	'7.0	53.55	40.16	30.6

14. WOOD PREPARATION

High quality fingerjoints require careful wood preparation. The extent of this will depend to some extent on the end use of the fingerjointed product.

As a minimum, ends should be squared and, if sniped, should be cut back to uniform size, and into clear straightgrained wood.

The sawyer doing this work should also be instructed in the grading rules for the product, and pieces containing defects in excess of those allowed should have the defects cut out, or if this would result in pieces too short for the fingerjointer they should be rejected.

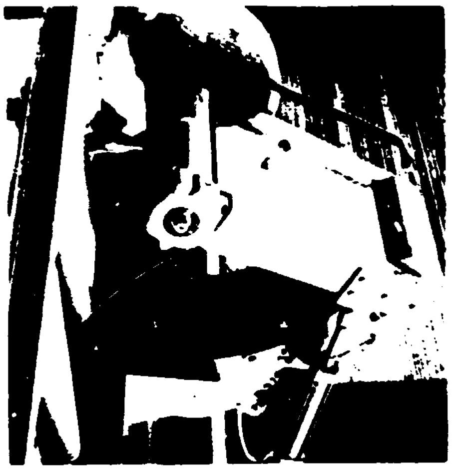
Pieces containing excessive crook or bow can be cut in half to straighten them. These freshly cut ends should be cut again to make them square. Twist is not reduced to any extent by cutting and rejointing, and excessively twisted pieces should be rejected.

The type of saw best suited to this work is a rising spindle crosscut saw controlled by a foot or knee pedal. Another common type is a pneumatic feed parallel-pendulum saw as shown in Fig. 17(a). Rather slower, but more versatile for a small workshop is a radial arm saw, shown in Fig. 17(b). The radial arm saw can be set to cut angles for other work if required, but does not have the production capacity of the other two types.

In any case, the saw should be fitted with a substantial roller bench with a heavy rear fence as shown in Fig. 18.

Provision should be made for removal of off-cuts. This may be a box situated under the saw which is carried away and emptied periodically or a chute leading to a flat belt waste conveyor.

Wood preparation systems may range from very simple single hand fed saws, up to multiple saw systems with automatic timber and waste handling conveyors. The cost and complexity of the system should in any case be reflected by its productive capacity.



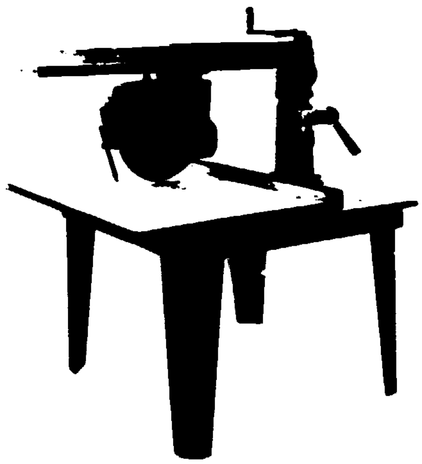


Fig. 17. (a) Pendulum saw (b) Radial arm saw

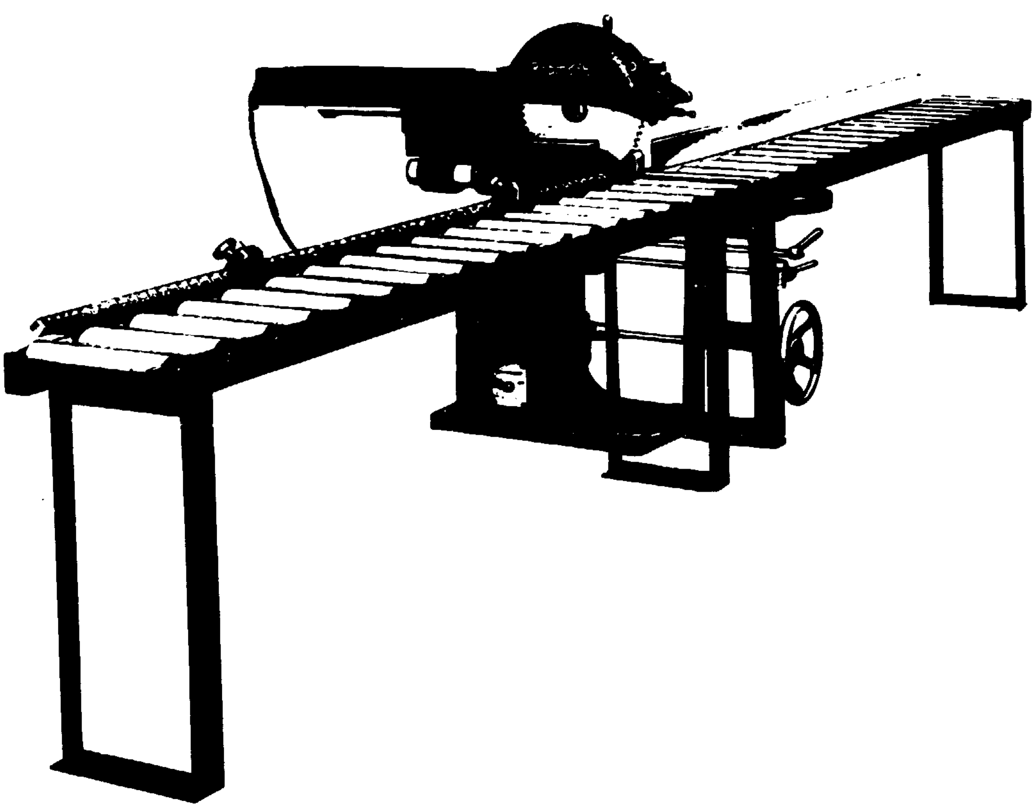


Fig. 18. Radial arm saw with substantial roller bench

15. CURING

After glueing, assembly, and pressing, the glue in the joints must be cured. Synthetic resin glues cure by a combination of temperature and time. Various methods of raising the temperature of gluelines exist. These include:

Radio frequency energy tunnels:
Direct heating of wood before assembly and pressing;
Elevated temperature tunnels.

On the other hand these glues will cure quite satisfactorily at ambient temperatures over 20°C provided the joints are undisturbed.

One major advantage of minifingerjoints (15 mm and shorter) is the very high wet strength they possess immediately after pressing, to the extent that a man can stand on a 5 cm x 5 cm freshly glued joint supported over a span of 60 - 70 cm without it breaking. This phenomenon appears to be a combination of friction and surface tension. This means that minifingerjointed timber can be handled after jointing quite satisfactorily provided that it is not dropped or jarred. Curing can, therefore, be done without any special equipment other than provision of adequate storage space and suitable transport equipment.

One fingerjointing factory which the expert built, with a daily output of about 30 m^3, was provided with four conveyor chains at 2 m centres, 20 m long. The freshly fingerjointed timber was stacked in packets at one end of the chains and by the time it had moved, packet by packet, to the far end it was cured and ready for further processing.

Note that this method of curing is only really satisfactory for minifingerjoints. Longer and blunter fingers may not develop sufficient wet strength to permit manual handling and stacking and may require mechanical handling and full length support of the pieces until curing of the glue is completed.

At the other end of the scale are radio frequency and direct high temperature curing. These produce fully cured fingerjoints as an integral part of the operation. However, they are expensive thereby requiring a high production level to recoup their cost, and especially in the case of radio frequency equipment introduce another high level technology with its consequent control and maintenance problems.

At an intermediate level of cost and complexity is a curing tunnel heated by hot air. In this type of curing tunnel, the boards are transported sideways individually on chains, and the surrounding chamber is heated by hot air from one of the numerous waste fired heating units manufactured for space heating. Depending on thickness, glue formulation and chamber temperature, a residence time of 30 to 60 minutes should result in fingerjoints cured sufficiently to withstand any normal handling or processing stresses.

16. CHOICE OF MACHINERY

There is a wide range of fingerjointing machinery available, and most major industrial countries which manufacture wood-working machinery have one or more manufacturers of fingerjointers.

The number of types of machine is almost bewilderingly large. Almost every possible variation of moving workpiece or moving cutter-head, single or multiple cutting, continuous or batch pressing etc. has been made and is on the market. Machines range from simple one at a time units to large fully automated plants where the wood is not touched until it emerges in fully cured, mechanically stacked packets.

This section endeavours to discuss some of the considerations involved in choosing a machine or evaluating machines on offer.

Performance. A specification should be prepared listing:

Maximum and minimum cross sections to be jointed:
Maximum and minimum lengths to be jointed:
Average length of timber;
Number of joints per day required:
Hard or soft wood; and
Any particular requirements for joint profile.

Requests for quotations may then be sent to manufacturers. These requests should include details of local electricity supply (voltage, frequency). It may be convenient to request at the same time, prices for spare cutters and for a suitable cutter sharpening machine.

The requirements for maximum and minimum lengths should be examined carefully and should be determined by a survey of the raw material available, expressed in percentage of total timber available in each increment of length. Some types of fingerjointers, particularly those incorporating turntables have absolute restrictions on maximum piece length. Major increases in machine price and lowering in production rates may result in insisting on a long input length capability, when average length is very much shorter and the long lengths would be coped with by cutting them in two and then re-jointing.

Joint Orientation - Horizontal or Vertical

Several factors must be considered in making this decision. A horizontal fingerjointer will have a shorter length of cutter, which is cheaper, and easier to mount and maintain, but each tooth will be working harder and will therefore require more frequent sharpening. Break out will be on the edge in a horizontal joint, on a face in a vertical joint. Breakout will be relatively infrequent in a machine which cuts packets of pieces since only the last piece in each packet can suffer, but this type of machine generally has high production capabilities and is expensive. Break out in a vertical joint will be of least effect if it occurs on the face opposite the reference face, since this is the face which is planed most heavily in final machining. However, relatively few vertical fingerjointers have the cutters emerging on the non-reference face.

Vertical joints, without break out, will generally give a stronger joint than horizontal. This is because splitting of finger roots and consequent substandard glue pressure of the associated fingers is generally confined to one or possibly two fingers away from the free edge.

In a horizontal joint the cross sectional area associated with these weaker fingers will occupy a larger area than in vertical joints, and proportionally less will be removed by finishing planing. However, if non-structural appearance joints are required as the main product, a horizontal joint will generally give a better finished appearance than a vertical joint, for equal degrees of cutter maintenance.

Summarising these various factors, the expert suggests:

Low level production - structural and non-structural = horizontal
Medium level production, non-structural = horizontal; structural = = vertical
High level production - structural and non-structural = vertical

Glue Application

Glue application may be by hand, for low level production, or by profiled roller or comb for higher level production. The major consideration here is ease of disassembly and cleaning of the glue applicator. The glue applicator should preferably run only intermittently, since a continuously operating pump and turning roller will shorten the pot life of the glue and will speed evaporation of volatile solvents such as methanol. In hot climates glue spreaders may have to be jacketed with refrigerated water, however, this is a further complication and expense. The expert suggests purchase of jacketed equipment for hot climates but at any rate initially not the chiling unit. This can come later if measures such as small batches of glue mixed from refrigerated resin prove inadequate.

Presses

There are various pressing arrangements possible. Some machines have this function integrated with the cutting mechanism. Where assembly and pressing are done separately from the machining, four types are possible.

Joint by joint: slowest
Length by length: capacity depends on the length of the press between clamps as well as cycle time
Continuous through feed: high capacity
Direct end pressure, working on cut to length assemblies.

The simplest type is the last, but it becomes unwieldly if lengths over about 8 m are manufactured. However, if the bulk of manufacture is, say 6 m moulding stock, it is probably the best choice. With suitable loading and unloading arrangements it can have a very high throughput. Continuous through feed presses have the highest production but are also the most complicated and difficult to maintain.

Control System

As the output of a fingerjointing machine increases, so does its complexity in degree of automation and interlocking and also its propensity to develop faults in control equipment. Potential purchasers should examine the complexity of controls carefully in order to assure themselves that maintenance of these items is possible in their local industrial environment. Consideration should be given to availability of both spares and skilled technicians. A moderately complex plant may require several hours attention per day from both a fitter and an electrician on routine maintenance. Without such skilled attention, it may well be that two simple low-output machines are preferable to a single complex one, even though the latter's rated output may be higher and its initial cost lower.