of the operations done and of the desire to eliminate human labour, with its greater cost and chances of inaccuracy in the finished product. On all machines there are numerous aids by which the fixing of the work is facilitated. Many of these consist of simple, packing blocks, by which heights are adjusted. These reach their higher developments in wedge-shaped packings, some of which are operated by a screw, while others act directly by screws. In some cases the exact height can be ascertained by observing graduations on the packings. Circular work is held in V-blocks, which occur in numerous modified forms. Various kinds of straps, clamps and bolts are used for gripping work with sufficient security to enable it to withstand the stress of the heaviest cutting. The highest development of all is attained in the templets and jigs, which are now indispensable in all modem shops, and which increase in number and complexity as the product of the shop becomes more specialized. A templet is a piece of metal cut to a definite shape, which being laid upon the work becomes a guide for striking the same shape on the surface of the work with a pointed scriber, and by which the tooling of any number of similar pieces is done without the labour of lining out each separate piece. Obviously, in such a case the degree of accuracy of the tooling still depends on the machine hand, who may work exactly, or only approximately, to these lines. Hence a great advance is made in the jig, which may be defined generally as a templet that is clamped rigidly to the work, or a box in which the work to be tooled is held. No marking off is done, but the jig becomes the actual guide for the operation of the cutting tools. the operation most frequently performed in jigs is drilling. Then the holes in the jig receive and coerce the drills, so that the holes made cannot vary’ in the least degree from those already in the jig. As it will often happen that hundreds or thousands of similar pieces will have to be tooled in this manner, holes in jigs are generally bushed with hardened steel which is capable of enduring very lengthy service, and which can be renewed when worn. This is a simple illustration, but many iigs are of an extremely elaborate character, for it is obvious that the cost of a jig, though it may run into many pounds, becomes a mere trifle when spread over some thousands of pieces of work.

XII.—Wood-working Machinery

There is a large range of various classes of tools for performing the operations on timber, from the rough log to the finished product. Division is effected by saws, planing and finishing to outlines by knives or cutters, boring by augers and smoothing by sandpaper.

The first operation is that of tree-felling, which is often effected by machine, consisting of a reciprocating blade, working horizontally in a frame and moved by a steam cylinder. The boiler is separate, so that the machine may be transported about and set to work over a considerable area, steam being conveyed to it by a flexible pipe. When the trees are brought into the saw-mills in the form of logs, *i.e.* with the branches lopped off, they are often cross-cut to reduce them to suitable lengths. This operation is effected either by a reciprocating saw, operated by a pulley and crank, or by an electric motor, or else with a circular saw, travelling on a carriage which moves the saw through the log laid in front of it. The next operation, that of division or breaking-down into smaller portions, is done by saws of various types, according to the class of work. The oldest form of machine is the frame-saw, which is still used very largely. It comprises a framing within which a saw-gate or saw- frame is reciprocated up and down by a crank; the frame holds a number of saws or webs of flat form, strained up tightly with wedges or cotters between the top and bottom, of the frame, the distance between the saws being capable of variation to suit boards of all thicknesses. The log is fed longitudinally to the gang of saws upon carriages, which are of two types. Tn the roller-feed, which is suitable for comparatively even and straight logs, ribbed rollers in front and behind the saws obtain a bite on the top and bottom of the timber and feed it forward by their rotation. In the rack-feed the log is mounted bodily upon a long carriage that runs by rollers upon a set of rails, and the carriage is travelled along by pinions and racks, which give a positive feed regardless of the shape of the log. The carriage in the roller-feed machines is only represented by a couple of plain trolleys supporting the timber at back and front. The feed is obtained through a friction wheel of V-shape, with a smooth pawl, called the silent feed; the wheel is given a partial rotation at each down stroke of the saw-gate to turn the rollers or the pinions for carrying forward the log. The division of the timber may be either into deals or flitches, or planks or boards. In the last-named case as many as fifty saw-blades are sometimes held in a frame.

For the more valuable hardwoods a single blade reciprocating saw, operated horizontally, is used very largely, the machine being termed a board-cutter. The log is clamped to a travelling table, passing underneath the saw, which is strained in a frame sliding on a cross-rail that can be adjusted up or down on a couple of up- rights like a planing machine. The saw is worked from a crank and connecting-rod. As only one board is sawn at a time the attendant is able to see the figuring of the timber and to avoid waste when bad places are encountered.

A machine much more rapid in operation is the horizontal band­saw, modelled on the lines of the above machine, but with a band- saw blade running over two pulleys, at a high speed, of about 7000 ft. per minute. The saws are very thin, so that a minimum of wood is wasted in the cut or “ kerf,” a very important consideration in dealing with costly woods. Vertical band-saws, having one pulley above the other so that the blade runs vertically, are very popular in America; they occupy less floor space than the horizontal types. It is necessary to present the log from the side, and it is therefore clamped by dogs upon a carriage running on rails, with provision for feeding the log laterally to the saw by sliding ways on the carriage.

The use of circular saws for breaking-down is confined chiefly to squaring up heavy balks, which need only a cut on each side, or for cutting thick slabs. The thickness of the saw entails considerable waste of wood, and a large amount of power is required for driving. The machines are termed rack-benches, and comprise a long divided table built up of thin plates and travelling past the fixed saw upon rollers, the movement being effected by a rack and pinion.

Re-sawing machines are those designed for further cutting-up deals, flitches, planks, &c., already broken out from the log, into boards and other scantlings. The deal and flitch frames are built on the model of the frame-saws first described, but with the differ- ences that roller feed is always used, because the stuff is smooth and easily fed, and that the back of the timber is run against fences to keep it moving in a straight line. In the double equilibrium frames, which are much favoured, there are two sets of saws in separate frames, connected by rods to opposite crank-shafts, so that as one frame is rising the other is going down ; the forces are thus balanced and vibration is diminished, so that the machines can be speeded rather higher. Re-sawing is also done on circular and band saws of various types, fitted with fences for guiding the timber and controlling the thicknesses.

The cross-cut saws constitute another large group. They are employed for cutting-off various classes of stuff, after breaking-down or re-sawing, and are of circular saw type. The pendulum saw is a suspended form, comprising a circular saw at the bottom of a hang­ing arm, which can be pulled over by the attendant to draw the saw through a piece of.wood laid on a bench beneath. Circular saws are also mounted in tables or benches and made to part off stuff moved Iaterally upon a sliding-table. When there is sufficient repetition work machines with two or more saws are used to cut one or more pieces to accurate length without the necessity for measurement.

The lighter classes of circular and band-saws, employed for sawing up comparatively small pieces of timber, embody numerous provisions for quickening output. The plain saw benches, with circular saws, are the simplest class, consisting merely of a framed table or bench carrying bearings for the saw spindle and a fence on the top to guide the wood. A mechanical feed is incorporated in the heavier machines to push the timber along. The rope-feed mechanism includes a drum driven at varying rates and giving motion to a rope, which is connected with a hook to the timber, to drag it along past the saw, roller supports on rails taking the weight at each end of the bench. Roller-feed saws propel the stuff by the contact of vertical fluted rollers placed opposite the fence. , Other classes of saws for joinery work, &c., are constructed with rising and falling spindles, so that the saw may be made to project more or less from the table, this provision being necessary in grooving and tonguing with special types of saws. The same effect is obtained by making the table instead of the spindle rise and fall.

As it is necessary to use different saws for ripping (with the grain) and cross-cutting, some machines embody two saws so that work can be cut to shape on the same machine. These "dimension saws ” have two spindles at the opposite ends of a pivoted arm that can be turned on a central pin to bring one or the other saw above as required. In cases where much angular and intricate sawing is done universal benches are employed, having in addition to the double saws a tilting motion to the table, which in conjunction with various special fittings enables the. sawyer to produce a large range of pieces for any class of construction.

Band-saws, which have a thin narrow blade, are adapted especially for curved sawing and cutting-out work which the circular saw cannot manage. The usual design of machine (fig. 65) comprises a stiff standard supporting a lower pulley in fixed bearings, and an upper one in a sliding bearing, which by means of a weight or spring is caused to rise and maintain an even tension on the saw blade as it is driven by the lower pulley, and runs the upper one. India-rubber tires are placed around the pulley rims to prevent damage to the saw teeth. The table, placed between the pulleys, may be angled for cutting bevel work. It is necessary, in order to do true work, to guide the saw blade above and below the cut, and. it is therefore run in guides consisting of flat strips, in combination with anti- friction rollers which take the backward thrust of the saw. Fret or jig saws are a small class with a vertical reciprocating blade, employed chiefly for cutting out interior portions which necessitate threading the saw first through a hole.

Planing machines, used for truing up the surfaces of wood after sawing, depend for their action upon rapidly revolving knives fastened to flat-sided cutter blocks. The simplest machines, the hand-planers, have a cutter cylinder revolving between two flat