CHAPTER X.

GILL SPINNING—ROPE YARN—BINDER TWINE—TRAWL TWINE AND SHOE THREADS.

Automatic Spinner.—Rope yarns are always spun directly from the sliver without any intermediate process, such as roving. Slivers of Manila, for instance, delivered in a narrow ribbon from the finishing drawings of the types shown in figs. 38 and 42, are most conveniently spun upon the automatic spinner, such as is shown in figs. 46, 47, and 48. A finer yarn from the same material may be spun on the frame shown in fig. 49.

The automatic spinner was first introduced in America by John Good. As shown in fig. 48, B is the can of sliver from the finishing drawing frame. It is placed behind the machine as shown, and the sliver drawn up and passed through the trumpet mouth C (which prevents the passage of knots), then through the feed rollers D, which are geared and given the same surface speed as the gill sheet E by means of a band and pulleys, as shown. The sliver passes through another trumpet mouth F before being pinned by the gills, which are placed on bars, and form a sheet, working in a similar manner as explained when speaking of the machine fig. 29. From the gills the fibres are drawn through the condenser apparatus F′, then between the cheeks of the stop motion lever G, through the twist tube H (where it receives its twist), round the haul pulleys I and I′, then round the guide pulleys J and J′ (upon the leg of the flyer K), from whence it passes to the bobbin L upon the stationary spindle M, upon which bobbin the twisted yarn is wound. The condenser F′ is the first point of interest in connection with the draft-regulating movement. It is in two pieces, the trumpet mouth F′ and the grooved cam-shaped nipping plug N, centred in the throat of the former, and which is intended to automatically contract and enlarge the size of the opening according to the size of the yarn, and at the same time to maintain a nip on the passing fibres. The condenser is mounted upon a vibrating piece O centred at P, and maintained in a vertical position by the spring Q. The upright piece O is also connected by a link to the short arm of a bell crank lever S, the long arm of which forms the belt shifter which shifts the belt T which drives the gearing V, the latter giving motion to the endless chain of gills

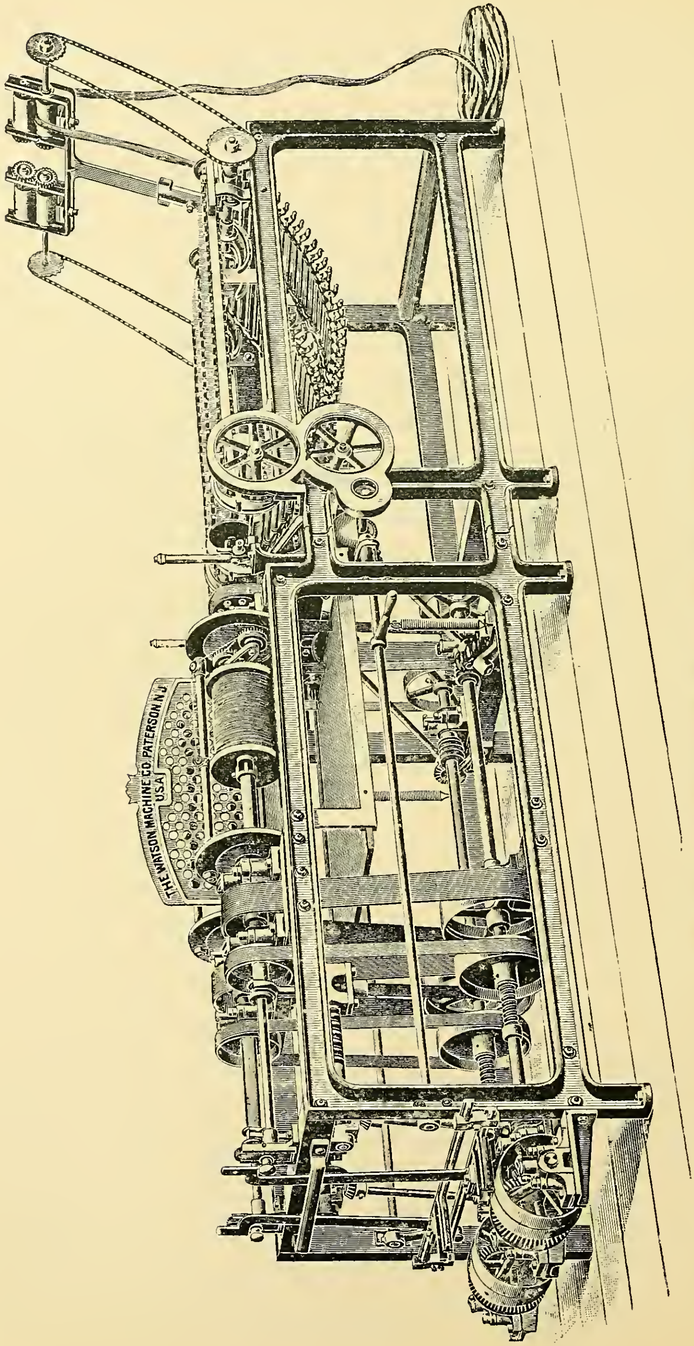


FIG. 46.—Automatic spinner for rope yarn and binder twine.

by means of the sheet belt W. The plug N is round, and fast upon an axle which passes through it. On one end of the axle is a handle to turn the plug and free the opening when required. In addition, on either end of the axle is a lever X by means of which the plug is automatically rocked. The plug is channelled on its periphery, the channel gradually deepening from its commencement until it terminates in a round shoulder formed in a steel block which is let into the plug. Condensation of the sliver takes place between the plug and a steel plate placed immediately above it, as shown. The nip is maintained by means of the balanced springs Y and Z attached to the arm X. The coiled spring Z is enclosed in a tube forming

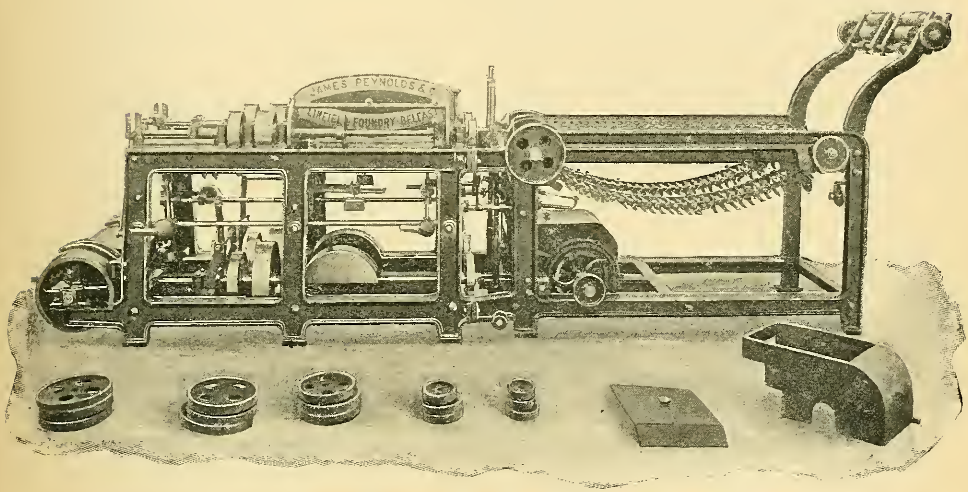


Fig. 47.—Horizontal automatic rope yarn and binder twine spinner. (As made by James Reynolds & Co., Belfast.)

a continuation of the vertical arm O, and is connected with an adjustable screw Q pendant from the closed end of the tube. The belt T is a round leather one of small diameter working on a grooved pulley $8\frac{5}{8}$ inches in diameter, and upon one of three flat faced pulleys all of the same size, viz., 8 inches. One of these pulleys is a loose one; another gives the average or ordinary speed to the gill sheet; while the third pulley gives the sheet a quick speed. When the upright arm O is in its normal position, with a yarn of the average diameter passing through the condenser F, the belt T is upon the medium speed pulley. When the upright arm O is pulled forward, by a thick portion of the sliver trying to get through the condenser, the belt is shifted on to the slack pulley and the gill sheet momentarily stops while the thick part is drawn out and the yarn levelled, when the condenser recedes again and the gill sheet starts once more. When a thin portion of the sliver reaches the condenser it tends to pass through the contracted opening more readily and the tension upon the upright arm O relaxes, permitting the spring Q to draw it backwards,

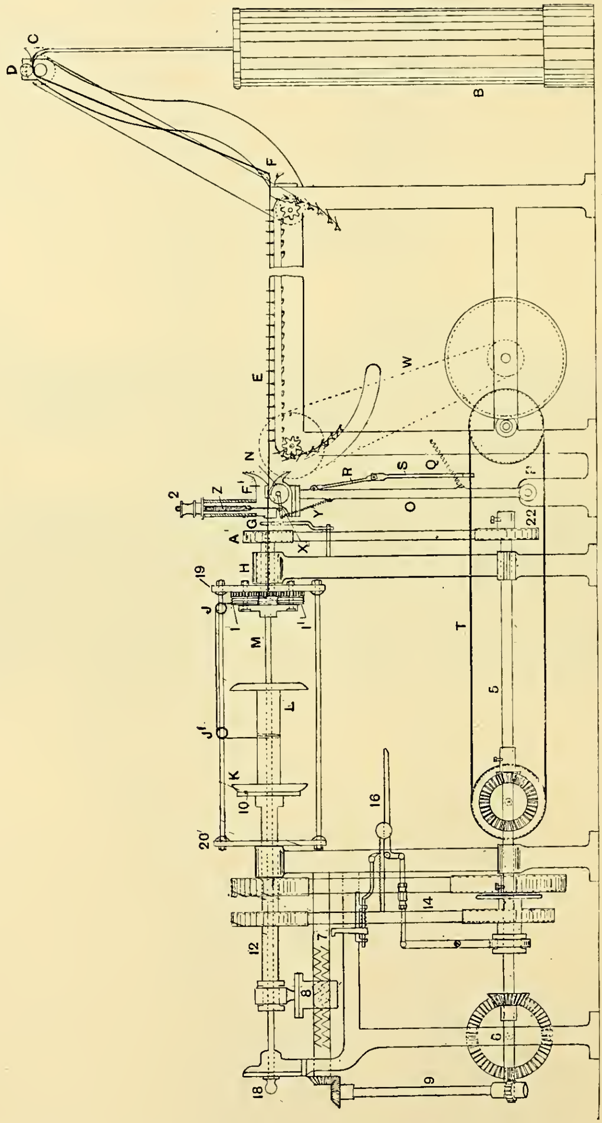


Fig. 48.—Automatic spinner for rope yarn and binder twine.

shifting the belt on to the quick speed pulley, and producing an increased supply of material to the condenser, and consequently uniformity in the yarn. The three driven pulleys, being of equal diameter, have naturally like velocities when the belt is upon them. The two different speeds are given to the gill sheet as follows :—The quick-speed pulley is fast upon the spindle upon which all three work. This spindle carries the larger of the two pinions shown, which has 29 teeth and drives the smaller of the spur wheels V of 130 teeth, producing the quick speed sheet. The slow speed pulley is fast on a sleeve which runs loose upon the spindle and carries the smaller of two spur pinions of 18 teeth which gears with the larger of the spur wheels V of 144 teeth and produces the ordinary speed at which the gill sheet runs. The third pulley is loose upon the spindle and gives no motion to the gill sheet. Of the two spur wheels V, side by side, the larger is loose upon the sheet pulley shaft. It has a ratchet cast upon its inner face with which a spring pawl on the inner face of the small spur wheel engages when the latter stops and the larger wheel becomes the driver. When the smaller wheel is the driver, the pawl naturally slips over the teeth of the ratchet. The grooved band pulley, $8\frac{5}{8}$ inches in diameter, receives its motion from the countershaft 5 through a bevel wheel of 72 teeth and a pinion of 18 teeth, as shown. The pinion may be placed at one side or the other of the bevel wheel in order to preserve the forward motion of the gill sheet, whether the countershaft turns to the right or to the left, giving the yarn right or left hand twist. The countershaft 5 receives its motion from the short shaft 6 carrying the frame pulleys, 12 inches in diameter, through the bevel wheels of 48 and 20 teeth, as shown. In order that the yarn, as delivered from the fixed point J′, may be built over the whole length of the bobbin, the latter is given a reciprocating motion by means of a traverse screw 7 and a screw block 8 fitting the screw. The screw 7 is driven by a bevel wheel on the end of the slanting spindle 9, which receives a slow motion from an endless worm on the end of the countershaft 5. The end of the bobbin has in it a small hole, protected by a metal ring, in which engages a pin 10 projecting from the disc of the long sleeve 12, both sleeve and bobbin being carried round by the pull of the yarn as the flyer revolves, and both having a reciprocating motion, on the stationary spindle, given to them by the screw block 8, as shown. The flyer K is driven at a constant speed of say 1600 revolutions per minute by means of pulleys $13\frac{1}{2}$ and $7\frac{1}{2}$ inches in diameter respectively, the former fast on the countershaft and the latter upon the flyer sleeve. The belt 14 encircling the bobbin drag pulley, is termed the "friction belt." The bobbin pulley is about the same size as the flyer pulley—namely, $7\frac{1}{2}$ inches. The drag pulley is smaller than the flyer driving pulley ($13\frac{1}{2}$ inches) ; consequently since it is the tension of the yarn which pulls the friction belt round, the drag pulley has a quicker speed than the flyer driving pulley. This loose drag pulley has a friction surface on one side which bears against a loose friction plate between the two pulleys. The drag pulley is pushed against the friction plate by means of cranks, actuated through links from the weighted lever 16, as shown.

The friction plate is prevented from running faster than the flyer by means of studs on its back surface engaging with a similar stud on the side of the flyer pulley. The friction between the two surfaces is automatically increased, as required by the augmenting diameter of the bobbin at each traverse, by means of the shifting of the weight along the lever, as shown. The full bobbin is removed and replaced by an empty one in drawing out the sliding and stationary spindle M by means of the knob 18 on its end. The flyer is composed of two discs 19 and 20, say 12 inches in diameter, joined by two stay rods as shown. Both these rods carry guide pulleys for the yarn, those on one arm serving for right and those on the other arm for left hand twist. The bottom of the groove of the pulley J is in the plane of the last groove of the haul pulley I. The usual size of flyer is about 12 inches by 26 inches, and that of the automatic bobbin 8 inches by 10 inches, with a barrel 2 inches in diameter and 1 inch bore. The pulley 22, on the extreme end of the countershaft 5, is termed the twist pulley. Its diameter depends upon the degree of twist required in the yarn. It drives a pulley A, 5 inches in diameter, forming part of the twist tube H, upon the other end of which is a small pinion of 21 teeth driving the haul pulley wheels on either side, each of 36 teeth. These are compounded with haul pulleys I and I′, of three grooves each, whose effective diameter is $3\frac{1}{2}$ inches. These haul pulleys run loose upon studs fixed in the disc of the flyer on one side and in a bridge piece which supports the end of the spindle, as shown, upon the other. The haul pulley drive is a sort of epicyclic or differential gear. If the twist tube were stationary, the flyer would carry the haul pulleys round the stationary pinion on the twist tube and give them motion in the same direction as itself. When, however, the twist pinion is run in the same direction as the flyer, it tends to drive the haul pulleys in the opposite direction. The speed given by the flyer is the greater, consequently the haul pulleys turn in the same direction as the flyer at a speed equal to the difference of the two contrary motions given to them by their two drivers. It is the amount of this difference, which may be regulated by the speed of the twist tube, which gives the draft, and affects both draft and twist. It is thus essential to the regularity in size and twist of the yarn that the twist belt should not slip, and that the flyer revolve at a constant speed. An example of the draft and twist for Manila binder twine or reaper yarn, 200 yards per lb., spun from sliver 50 yards per lb., will suffice to show the principle of the draft and twist calculation. Suppose that the twist tube driving pulley 22 be 8 inches in diameter and that the countershaft 5 runs at a speed of 864 revolutions per minute. The speed of the flyer is then $\frac{864 \times 13\frac{1}{2}}{7\frac{1}{2}} = 1555{\cdot}2$ revolutions per minute, and that of the twist tube $\frac{864 \times 8}{5} = 1382{\cdot}4$ revolutions per minute. One revolution of the twist tube gives the haul pulleys $\frac{21}{36}$ of a revolution in one direction, while one revolution of the flyer gives the haul pulleys the same motion in the other direction. The speed of the flyer is the greater, however, so that the effective motion of the haul pulleys is $\left(\frac{1555 \cdot 2 \times 21}{36}\right) - \left(\frac{1382 \cdot 4 \times 21}{36}\right) = 907 \cdot 2 - 806 \cdot 4 = 100 \cdot 8$ revolutions per minute. Their effective diameter being $3\frac{1}{2}$ inches, they draw through $\frac{100 \cdot 8 \times 3 \cdot 5 \times 3 \cdot 1416}{12} = 92 \cdot 4$ feet per minute. Since the flyer makes 1555·2 revolutions per minute, $\frac{1555 \cdot 2}{92 \cdot 4} = 16 \cdot 8$ turns per foot of twist are put into the yarn. The rate at which the yarn is drawn away and wound upon the bobbin we have ascertained to be 92·4 feet per minute. To calculate the draft we require to know the speed at which the sliver is led forward or the surface speed of the gill sheet, both at quick and slow speed. From the particulars already given we find that the speed of the wheel V of 144 teeth is $\frac{864 \times 18 \times 8\frac{5}{8} \times 16}{72 \times 8 \times 144} = \frac{207}{8} = 25 \cdot 9$ revolutions.

If the change pulley for the sheet which is fast upon this axle be 5 inches in diameter and the pulley which it drives on the chain gill sheet front roller 10 inches in diameter, with a sprocket wheel of 7 teeth driving the sheet whose bars have a pitch of $1\frac{2}{3}$ inches, the speed of this sheet in feet per minute will be $\frac{25 \cdot 9 \times 5 \times 7 \times 1\frac{2}{3}}{10 \times 12} = 12 \cdot 6$, so that the draft thus appears to be $\frac{92 \cdot 4}{12 \cdot 6} = 7 \cdot 3$. When the belt is on the pulley giving the gill sheet its quick speed, the draft is $\frac{7 \cdot 3 \times 16 \times 130}{29 \times 144} = 3 \cdot 6$, so that the actual draft varies between these two figures according to the inequalities in the sliver. The changing of the twist tube driving pulley 22 changes both draft and twist. It must be borne in mind that the change effected is out of all proportion to the difference in size of the pulleys, even a quarter of a inch in the diameter of the pulley making a very great difference in both the size and twist of the yarn. The draft alone is changed by increasing or diminishing the rate of feed by changing the lower of the two sheet pulleys in the inverse proportion to the draft required. The stop motion lever C is balanced by the tension of the yarn passing between its cheeks. When the yarn runs light or fails to pass through the twist tube, the lever falls, releasing the belt forks, shifting the belt on to the slack pulley, and applying a brake to a friction pulley generally placed on the shaft 5. The flyer is thus brought quickly to rest. As may be seen in fig. 46, each automatic spinner has two spindles running independently side by side. The flyers, owing to the danger attached to them in consequence of their speed and weight, are often protected by a circular iron cover with a sliding door in the top. In practice, the twist and flyer belts must be kept tight, while the tension of the drag or friction belt is rather less. The yarn must be wound around the haul pulleys in the direction of rotation of the flyer, otherwise the machine will not work at all. This machine works very well on yarns spun from hard fibre, the weight of the yarns varying from 80 to 2000 yards per lb.

Binder Twine or Reaper Yarn.—In the automatic spinner shown in fig. 46, which is of American construction, belts have been replaced by gearing wherever possible in order to insure uniformity of product. Owing to the enormous quantities of binder twine employed in America every harvest, the United States are the largest users of hard fibre in the world. There

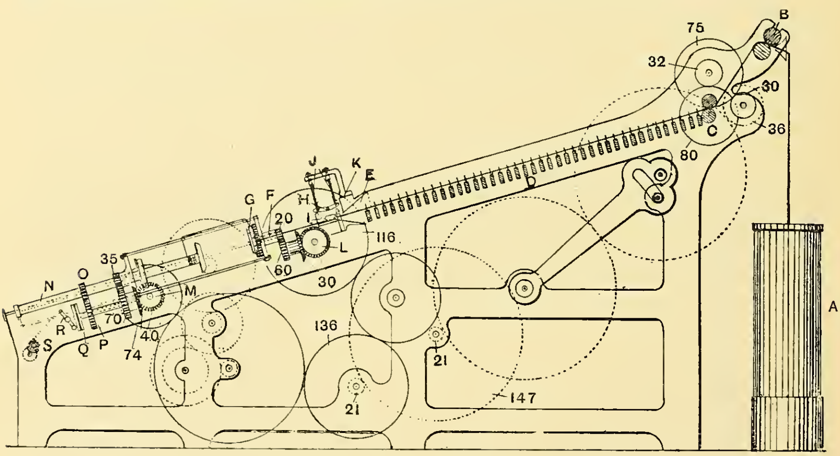


FIG. 49.—Lawson's inclined spindle gill spinning frame.

are many large rope works, one of the principal being the M'Cormick binder twine mill in Chicago, which has a capacity of 90 tons of binder twine per day.

Lawson's Gill Spinning Machine.—For lighter yarns from similar material, say yarn of 360 yards per lb. from the best white Manila, a machine rather differently constructed is required. Fig. 49 shows such a machine, which is known as Lawson's inclined spindle gill spinning machine. A is the can of sliver from the finishing drawing frame. As shown, the sliver is lifted from the can by a pair of rollers B, which deliver it to a pair of feed rollers C. As it issues from these latter it is "pinned" by the gills, on the faller bars D, which work in the ordinary way on the screw gill principle as described in Chapter VIII. From the gills the material is drafted through a trumpet mouth arrangement E and a twist tube F, by means of haul pulleys G, of similar construction, and working in the same way as those of the automatic spinner which we have just described. Unlike the latter, however, this machine has no draft-controlling mechanism, its trumpet mouth merely serving to retain and draw out lumps, etc., and to maintain such a grip upon the fibres as will prevent them from being "gulped." The condensing trumpet mouth is formed by an eccentrically grooved roller H and a grooved block I, the grooves forming a tapering passage for the sliver. The roller H is held in position by springs J, acting upon arms projecting from the roller axle in opposite directions, as shown, and by the frictional drag of the sliver on the roller, by which means a light nip is maintained, the twist running up to this point. The bracket K, carrying the roller, is hinged to the block I, and held down by a spring hook. The bracket K is also constructed to form the upper half of the trumpet mouth, guiding the sliver to the nip. It will be noticed that in this machine the gills and spindles are both mounted at the same inclination, the object being to allow the sliver to pass in a direct line through the nip. The theory of the drafting, twisting and winding is similar to that of the automatic spinner, the method of driving the parts and the construction of the machine alone being different. This machine has usually six spindles side by side, and is adapted for an 8 × 4 inch bobbin. Gearing takes the place of belts in the flyer and twist tube drives and in dragging the bobbin, and has the advantage that, being a positive drive, the weight and twist of the yarn cannot be affected by slipping belts, as in some makes of automatic spinners. The twist tube is driven through an intermediate wheel, as shown, by a shaft L running across the frame, upon which shaft is the wheel of 116 teeth, which is driven from the driving shaft by change gearing. The flyer is driven through intermediates from another cross shaft M, also driven by gearing from the pulley shaft. The bobbin is, as before, pulled round by the tension of the yarn and connected by a pin with the sliding sleeve N, which has upon it a pinion O, upon a feather, which pinion gears with a wheel P compounded with the friction disc Q, upon which additional pressure is applied as the bobbin fills by the lever R, actuated through a chain by a shaft S, upon which the chain is wound, and which gets a semi-turn through a worm compounded with a ratchet wheel which is moved by a detent at each traverse of the bobbin in a manner which will be readily understood.

As the calculations for draft and twist upon this machine are rather difficult, we will give particulars of the wheels and speeds in detail. The draft is the ratio between the length of sliver taken in by the feed rollers in a given time and the length of yarn which in a like space of time passes over the haul pulleys and is wound upon the bobbin.

Taking one minute as the unit of time and the speed of the frame pulley as 450 revolutions per minute, we find the length of sliver taken in by the back roller as follows:—Upon the other end of the frame shaft from that upon which the driving pulley is keyed, is a pinion of 21 teeth driving the large stud wheel of 147 teeth. Compounded with this stud wheel is another pinion of 21 teeth driving the back shaft or draft change wheel of 36 teeth, through the two large spur carriers shown. Upon the other end of the back shaft is a pinion of 30 teeth driving the stud wheel of 75 teeth, compounded with the stud pinion of 32 teeth driving the back or feed-roller wheel of 80 teeth at a speed of $\frac{450 \times 21 \times 21 \times 30 \times 32}{147 \times 36 \times 75 \times 80} = 6$ revolutions per minute. The circumference of the back roller, which is 3 inches in diameter, is $3 \times 3{\cdot}1416 = 9{\cdot}4$ inches, so that it draws in $6 \times 9{\cdot}4 = 56{\cdot}4$ inches of sliver per minute.

To find the length of yarn delivered to the bobbin by the haul pulleys in the same time, we proceed, as in the automatic spinner, to find the difference between the power of the flyer and the twist tube drives. Motion is given to both flyer and twist tube from a speed wheel of 136 teeth upon the frame shaft. This wheel drives the wheel of 74 teeth upon the flyer shaft through the large intermediate shown. Upon the flyer shaft are bevels of 40 teeth, gearing with similar bevels upon studs.

Compounded with the latter are spur pinions of 70 teeth driving the flyers through pinions of 35 teeth at a speed of $\frac{450 \times 136 \times 40 \times 70}{74 \times 40 \times 35} = 1654$ revolutions per minute.

The twist tubes are driven in a similar manner to the flyers, through a wheel of 116 teeth upon the cross shaft, upon which are bevels of 30 teeth driving stud bevels of similar size, which latter are compounded with spur wheels of 60 teeth driving the twist tubes, through pinions of 20 teeth, at a speed of $\frac{450 \times 136 \times 30 \times 60}{116 \times 30 \times 20} = 1582$ revolutions per minute.

Upon the inside ends of the twist tubes are pinions of 20 teeth, gearing with similar pinions upon the haul pulleys. The velocity given to the haul pulleys by the twist tube drive is thus equal to 1582 revolutions per minute. The flyer revolves in the same direction as the twist tubes, and carrying round with it the haul pulleys, tends to give them a velocity of 1654 revolutions per minute in the direction opposite to that of the 1582 revolutions given by the twist tube. The effective speed of the haul pulleys is thus $1654 - 1582 = 72$ revolutions, and their diameter being $2\frac{3}{8}$ inches, the length of yarn drawn through per minute is $72 \times 2{\cdot}375 \times 3{\cdot}1416 = 537$ inches. Since the rate of feed is 56·4 inches and that of delivery 537 inches per minute, the draft of the frame is $\frac{537}{56{\cdot}4} = 9{\cdot}5$. The turns per foot of twist being put into the yarn, the speed of the flyer being 1654 revolutions and the rate of delivery $\frac{537}{12}$ feet per minute, are $\frac{165 \times 412}{537} = 37$.

To produce yarn about 400 yards per lb. from Manila hemp, Lawson's gill spinner should have—

Length of reach	80 inches
Breadth of gill	$1\frac{1}{2}$,,
Pins per inch (1 row)	8 ,,
Length of pin out of stock . . .	$\frac{3}{4}$ inch
Pitch of screw	$1\frac{5}{16}$,,

Gill Spinning Frame for Rope Yarn.—Rope and twine yarns from tow

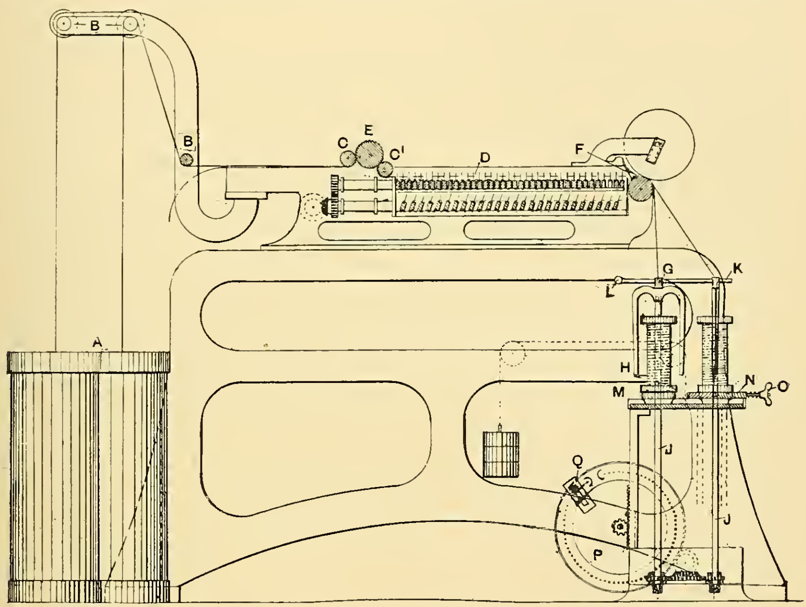


Fig. 50.—Gill spinning frame for rope yarns.

and soft hemp are most conveniently spun upon a gill spinning frame of the roving frame type shown in fig. 50.

As before, A are the cans of sliver from the finishing drawing frame and C the feed rollers. B are the sliver guides over which the sliver passes as it is drawn from the can, and D the faller bars and gills working in screws in the ordinary way. The arrangement of feed rollers, screw gills and drawing rollers, is in fact just the same as described in the previous chapter when speaking of the drawing frame. Leaving the drawing rollers, the sliver passes through a hole in the head of the flyer, down the leg and on to the bobbin. The flyer is of steel, and the hollow leg works equally well with or without a "curl," or eye, H, upon the extremity of its leg. The flyers are fast upon the top of the spindles J, which are driven at a constant speed by gearing, as shown, from the frame shaft. The long and heavy spindles, usually driven at a rather high speed, are steadied by the plate K, which fits over the spindle tops and flyer heads, and which, being hinged at L, may be raised to remove the flyers and full bobbins. The bobbins are pulled round by the tension of the yarn. They rest upon the carriers M, with which they engage by means of pins, as shown, and which they pull round with them. A suitable drag is applied to the bobbin by means of wooden friction brakes, one of which is shown at N. These are composed of two wood blocks which surround the carrier, upon which they are pressed with more or less intensity, as the thumb screw O is turned and the blocks tightened together.

The yarn is built upon the bobbin in a regular manner in consequence of the up-and-down motion of the builder with the carriers upon which the bobbins rest. This up-and-down motion, which in this machine is constant and regular, both as regards speed and length of traverse, is given by means of a wheel P, known as the "mangle wheel," which is frequently met with in spinning machinery, and which, acting in conjunction with a rack and pinion, gives the required motion in a manner now to be described. The driver of the mangle wheel is a small pinion Q, keyed upon the end of a shaft, driven by gearing from the other side of the frame. This shaft is not rigidly carried, so that its extremity, with the pinion which it bears, can change its position, in the slotted bracket shown, when the mangle wheel is moved round to a position such that the last of its teeth is in gear with the small driving pinion. The teeth of the mangle wheel are brass pins ranged in an uncompleted circle. As the pinion reaches the last pin at either end it moves round it, being assisted to do so by the semicircular guides shown. It will be seen that the pinion, which constantly turns in the same direction, drives the mangle wheel alternately in opposite directions, giving the builder its up-and-down motion in a manner easily understood from the drawing.

Fine Gill Spinning Frame.—Finer gill spun yarns, which cannot stand an excessive strain in the winding on, are often spun upon a similar frame furnished with a differential motion, and which has all the characteristics of a roving frame, such as we will describe in our next chapter. The differential motion varies and governs the speed of the bobbin and builder as the former fills and maintains a uniform tension upon the thread.

Sometimes the gill spinning frame for fine yarns is fitted with a similar builder, tape-driven spindles and fish-tailed flyers as those used in the dry spinning frame, which will be described in Chapter XII. In this case the bobbins are dragged by drag bands which bear against the grooved base of the bobbin, the motion of which they retard sufficiently to permit of the flyer winding on the yarn as spun.

The degree of twist put in by all types of spinning and twisting frames depends upon the ratio between the speed of the flyer and the rate of delivery. For very coarse yarn, such as rope yarn, for instance, the degree of twist is indicated in turns per foot run, while for finer yarns the number of turns per inch is spoken of.

For rope yarns the number of turns per foot twist required equals the product of 3·75 and the square root of the number of the yarn. For 25's spun yarn, for instance, the correct twist will be $\sqrt{25} \times 3{\cdot}75 = 5 \times 3{\cdot}75 = 18{\cdot}75$ turns.

Basis of Rope Yarn Numbering.—The number of rope yarn indicates the number of threads of that yarn which will be required to make one of the three strands which will form a rope 3 inches in circumference. No. 40, for instance, indicates that three strands of 40 threads each, or 120 threads in all, make a rope 3 inches in circumference. The weight of 100 yards of No. 40 rope yarn may be calculated as follows :—The weight of 100 yards 3 inch circumference white rope averages about 84 lbs. The contraction by twist being about 25 per cent., each of the single yarns composing the rope must have a length of 125 yards, or the total length of the 120 strands will be 15,000 yards. Since this length weighs 84 lbs. or 1344 ozs., 100 yards weighs nearly 9 ozs. Similarly, No. 20 rope yarn equals 18 ozs. per 100 yards, No. 30 weighs 12 ozs., and No. 18, 20 ozs., etc.

Heavy jute yarns are likewise gill spun upon a frame of the roving frame type. The number of jute yarns, as also of heavy flax yarns under the Scotch system, is the weight in lbs. of four hanks, or 14,400 yards. The number of flax and hemp yarns under the English system of numbering, indicates the number of cuts or leas, of 300 yards each, contained in one pound weight. Consequently to reduce Scotch to English numbers, it is sufficient to divide 48, or the number of cuts per Scotch spyndle, by the number or weight in lbs. per spyndle. Thus, 3 lbs. Scotch yarn $= \frac{48}{3} = 16$'s lea English.

The average twist required per inch by flax, hemp, and jute yarns may be taken to be the product of 2 and the square root of the number of leas of 300 yards contained in one pound. Thus the number of turns per inch twist necessary for 16's lea equals $2 \times \sqrt{16} = 2 \times 4 = 8$ turns. 16's lea English equals $\frac{48}{16} = 3$ lbs. Scotch yarn, so that to find the twist for any given weight of Scotch yarn we may take as a basis the turns per inch required by 3 lbs. yarn. The number of turns per inch required by any other Scotch number is then obtained by multiplying the turns per inch for 3 lbs. yarn by the square root of 3 and dividing by the square root of the number of the yarn to be twisted. Thus the twist required for yarn 5 lbs. per spyndle at the rate of 8 turns per inch for 3 lbs. yarn is $\frac{8 \times \sqrt{3}}{\sqrt{5}} = \sqrt{\frac{64 \times 3}{5}} = 6{\cdot}2$ turns per inch.

The reason that the square root of the number is introduced into the twist calculations is that the twist should vary inversely as the diameter of the thread, and that the diameter of the thread varies as the square root of the lbs. per spyndle, or inversely as the square root of the number of leas per lb.

Thus, to give No 40 rope yarn, for instance, its standard twist, or $\sqrt{40} \times 3{\cdot}75 = 6{\cdot}32 \times 3{\cdot}75 = 23{\cdot}6$ turns per foot, upon a gill spinning frame of the roving frame type, having a wheel of 102 teeth upon the delivery roller and driving the twist change pinion through intermediates, the number of teeth in the twist change pinion will be found to be 25, if the remainder of the gearing be as follows :—Stud carrier 64 teeth, spindle shaft wheel 44 teeth, spindle shaft bevels 28 teeth, and spindle pinions 19 teeth. For, the circumference of the boss roller being 4·4 inches, the spindles must make $\frac{23{\cdot}6 \times 4{\cdot}4}{12} = 8{\cdot}65$ turns for one of the delivery roller, to accomplish which the twist change wheel must have $\frac{102 \times 64 \times 28}{8{\cdot}65 \times 44 \times 19} = 25$ teeth.

In order to lay outstanding fibres and to give the yarn a smoother appearance, gill spinning frames with delivery roller and vertical spindles are frequently furnished with a damping roller which is placed between the point of delivery and the spindles. It has as many bosses as there are spindles in the frame. Each boss is flannel covered, and all are partly submerged, and turn in a trough of water which keeps their surface constantly damp. The yarn, while being twisted, bears against this damp surface, and a smoother yarn is consequently produced.

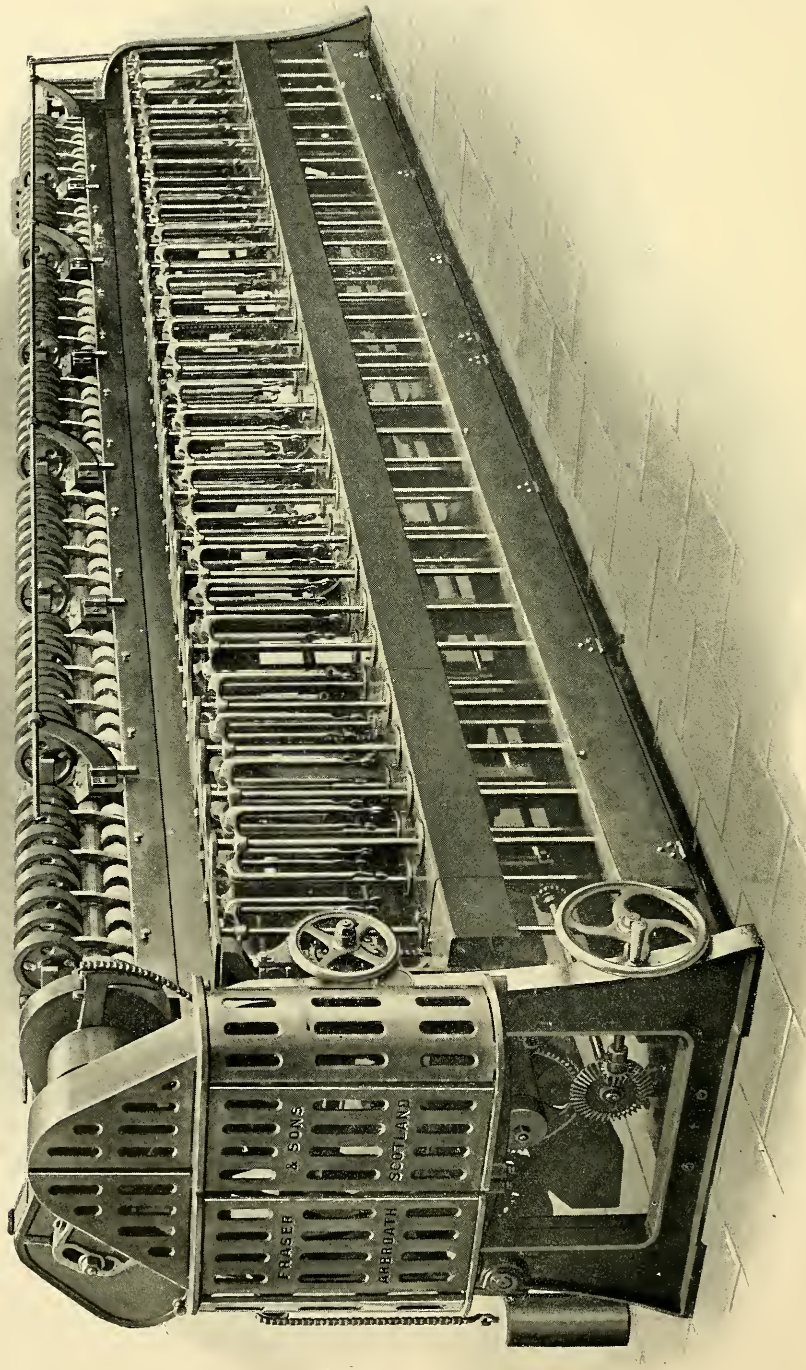


FIG. 51.—Fraser's patent spiral roving frame.

CHAPTER XI.

THE FLAX, HEMP, JUTE, AND RAMIE ROVING FRAME.

Spiral Roving Frame.—The roving frame is the last machine of the series in the preparing room. When the sliver reaches this frame, it has been drawn out to such an extent that if it is to be drawn out still further it must be given a slight twist to strengthen it, and must be wound upon a bobbin or spool. For these purposes, the roving frame, which is in reality a drawing frame, must be provided with spindles and flyers which are placed vertically in front of the boss or delivery roller.

Fig. 51 gives a general view of a screw gill roving frame as made by Messrs Douglas Fraser & Sons, Arbroath, Scotland. The same firm are the makers of a push-bar roving frame for jute, which works on the same principle as their "Ring" drawing frame, fig. 45. Quick gill bars necessitate quick spindles, and those referred to have been run at 900 revolutions per minute for years without undue wear.

In general appearance the frame resembles the gill spinning frame shown in section in fig. 50, but it is provided with additional mechanism, as are some gill spinning frames for fine work, to prevent excessive strain being put upon the roving as it is being wound upon the bobbin.

The drafting arrangements of the roving frame are practically the same as in the drawing frame; the gills are, however, finer, and the front conductor proportionate in width to the weight of sliver produced, being frequently only $\frac{1}{8}$ inch in width. It has always been the custom to arrange the spindles, to the maximum number of about 80 or 90, in two rows of 30 to 45 spindles each. Experiments are now being made, however, upon fine frames, to increase the number of spindles twofold by using wider gills, with two slivers abreast per row, and arranging the spindles in four rows instead of two. Usually, no doubling takes place upon the roving frame, only one can from the third or fourth drawing being put up at the back for each spindle. The frame is consequently much longer than the drawing frame, having sometimes nine heads of ten spindles or 90 spindles in all. The spindles are of steel 2 to 3 feet long and $\frac{1}{2}$ to $\frac{3}{4}$ inch in diameter. The spindle "foot" rests in a brass step set in the step rail. The spindles are supported in a vertical position by brass collars fixed in the builder. These collars should be long, projecting on the under side below and on the upper side level with, the top of the builder, thus forming a sleeve or socket upon which the wharves or carriers may run without wearing the spindles. The length of the spindle must be at least 3 inches longer than twice the traverse of the largest bobbin to be used, plus the depth of the builder and step rail from step to cover. The top of the spindles are fitted to receive the flyers, which are of wrought iron or steel. The mode by which the flyer is attached to the spindle top must be such that it can be easily removed and replaced when doffing, but at the same time remain firmly in position when working. Perhaps the best is the patent of Hattersley, the method employed being a spiral groove cut in the spindle top, the groove terminating in a round stop. This groove receives a small round button, fixed inside the socket of the flyer, the revolving spindle keeping the button pressed against the end of the groove.

Another method of attachment consists in one or more vertical grooves or keyways cut in the top of the spindle, the socket of the flyer having corresponding ribs or feathers. It should be impossible for the flyer to be pulled off by entangled rove, etc., while working. Were this to occur, damage to itself, the rove on the bobbin, or the other flyers would result. The neck and leg of the flyer are hollow, the latter being split to facilitate threading. The rove enters the neck, passes to the leg through one of two lateral holes, and is thence led through the flyer eye, which is of the ordinary curl pattern, on to the bobbin.

In Ireland the rove is usually passed direct from the hole in the neck to the leg of the flyer. Some Continental spinners pass the rove almost completely round the neck before leading it through the leg of the flyer, believing that in doing so they get a smoother rove and localise the tension and strain in the twisted portion of the slubbing. The spindles are driven from the frame shaft at a speed of 400 to 900 revolutions per minute. Take a frame, for instance, where a speed wheel of 84 teeth, upon the frame shaft, drives through a train of intermediate spur wheels a wheel of 44 teeth upon the spindle shaft. A number of bevels, of 28 teeth each, drive pinions of 19 teeth keyed upon the spindles. In this frame the spindles will make $\frac{84 \times 28}{44 \times 19} = 2{\cdot}8$ revolutions for one of the frame shaft. Suppose that the line shaft makes 177 revolutions per minute, and that a 20-inch drum upon it drives a pulley 24 inches in diameter upon the frame shaft. The latter thus makes $\frac{177 \times 20}{24} = 147{\cdot}5$ revolutions per minute, and consequently the spindles make $147{\cdot}5 \times 2{\cdot}8 = 413$ revolutions per minute.

In frames of various makers the speed of the spindles usually bears a fixed ratio to that of the frame shaft.

In Lawson's it has been found to be as 2·8 : 1, in Combe's 2·4 : 1, and in Fairbairn's 3 : 1. The wharve, or bobbin carrier, consists in a round platform, upon which the base of the bobbin rests. The under portion of the carrier is a bevel or spur pinion, by means of which motion is given to it from the socket wheel running loose upon the frame shaft. The wharve runs upon the top portion of the brass neck which surrounds the spindle. Its flat face has one or more pins projecting from its surface, which engage in corresponding holes in the base of the bobbin.

The bobbins have generally a barrel of ash with sycamore or beech ends, but for very fine work it is advisable to employ a finer wood, extra well finished and polished. The bore of the barrel is chambered to reduce friction on the spindle. The sizes of bobbins range from $4\frac{1}{2}$ inches to 12 inches traverse, with $2\frac{1}{2}$ inch to 5 inch heads. The speed of the wharves, and, consequently, of the bobbins, usually bears the same ratio to that of the socket wheel as does the speed of the spindles to that of the frame shaft. Thus in the frame we have taken as an example, a socket wheel of 105 teeth drives, through a link motion of spur intermediates, a wheel of 55 teeth upon the bobbin shaft. A number of bevel wheels of 28 teeth upon this shaft drive the pinions, each of 19 teeth, which form part of the wharve. Thus for one revolution of the socket wheel the wharves make $\frac{105 \times 28}{55 \times 19} = 2·8$ revolutions. If the differential wheel were fixed, the socket wheel would revolve at the same speed as the frame shaft, as will be explained later on, and therefore the bobbins would revolve at the same speed as the spindles. It is by running the bobbins at a different speed from the spindles, however, that the winding on of the rove upon the former is effected, and it is to govern and maintain this difference in speed that that beautiful piece of epicyclic gear known as the differential motion, or sun and planet wheels, was introduced, constituting as it does one of the most complex motions in textile mechanism.

The fine and light sliver delivered from the roving frame boss roller—one ounce often containing 500 yards—could not be wound upon and again unwound from the bobbin without giving it a small degree of twist to strengthen it. The amount of twist required varies from one-half to two turns per inch for any given material, being directly as the square root of yards per ounce, and inversely as the square root of the weight of unit length, or inversely as the diameter of the rove. The speed of the spindles being constant, the twist is altered by changing the speed of delivery or the velocity of the boss roller. This is done by increasing or decreasing the number of teeth in a wheel known as the twist change pinion, which lies in the train of gear which communicates motion from the frame shaft to the boss roller. In old frames it is often a driver, placed on the end of the frame shaft, and consequently must be *decreased* in size when changing from coarse to fine rove. In modern frames it is also a driver, being compounded with a socket wheel on a stud. If this be the case it must also be *decreased* in size when changing from coarse to fine rove. Taking the same frame as before, and following the gearing from the boss roller to the spindles, we have a wheel of 102 teeth upon the boss roller, driving through intermediates a twist change wheel of say 34 teeth, compounded with a stud carrier of 64 teeth, driving through some more intermediates a wheel of 44 teeth upon the spindle shaft. A series of bevels of 28 teeth, upon this shaft, drive the spindles, upon which are pinions of 19 teeth. The spindles thus make $\frac{102 \times 64 \times 28}{34 \times 44 \times 19} = 6{\cdot}43$ revolutions for one of the boss rollers, which—the boss roller being 4·4 inches in circumference—means $\frac{6{\cdot}43}{4{\cdot}4} = 1{\cdot}46$ turns per inch twist. Supposing that this twist has been found suitable for rove 320 yards per ounce, and it is desired to change the frame on to rove 200 yards per ounce, the nature of the material being the same, the requisite twist pinion may be found by multiplying the existing twist pinion by itself and by the present yards per ounce of rove, dividing by the new yards per ounce of rove, and extracting the square root of the result. Thus we get $\sqrt{\frac{(34 \times 34) \times 320}{200}} = \sqrt{1849} = 43$ as the required twist pinion. The reason for this is that the number of teeth in the twist pinion is inversely as the twist, which twist varies directly as the square root of the yards per oz.

Turns per inch of Twist Required.—The amount of twist which rove requires depends very much upon the nature, length and strength of the material of which it is composed, warp flax requiring less twist than weft flax, and weft flax less than tow for the same weight of rove.

In reality, all that is required is to give the yarn sufficient strength to be drawn off the bobbin by the feed roller of the spinning frame and through the hot water trough, when required, without drawing or breaking. The smaller the excess above this minimum strength, the more easily and regularly can it be drawn upon the minimum reach. A few examples from actual practice will give some idea as to the amount of twist required to give various weights of rove sufficient strength. (1) A tow rove 40 yards per ounce, destined to spin 14's lea from Russian dew-retted tow, required 0·84 turn per inch twist. (2) A tow rove 64 yards per ounce, destined to spin 25's lea from Russian dew-retted machine tow, required 1·05 turns per inch twist. (3) A tow rove 90 yards per ounce, destined to spin 40's tow warp from Irish machine and sorting tow, required 1·05 turns per inch twist. (4) A certain line rove 100 yards per ounce, intended to spin 40's lea light warp from Russian dew-retted flax, required 0·85 turn per inch twist. (5) A line rove 150 yards per ounce, destined to spin 70's lea light warp from

Courtrai long line flax, required 0·97 turn per inch twist. (6) A line rove 225 yards per ounce, intended to spin 50's lea prime warp from Irish long line flax, required 1 turn per inch twist. (7) A line rove 260 yards per ounce, fit to spin 100's lea light warp from Flemish long line flax, required 1·3 turns per inch twist. (8) A line rove 300 yards per ounce, intended to spin 120's lea light warp from Courtrai long line flax, required 1·41 turns per inch twist; and (9) a line rove 400 yards per ounce, fit to spin 140's lea light warp from Courtrai long line flax, required 1·56 turns per inch twist.

The writer has known rove to be correctly twisted on the same frame with the same twist pinion, although differing in weight by 100 yards per ounce. A constant number may be found for any frame, which, divided by the turns per inch twist required, gives the necessary twist pinion. Taking our previous figures, we first find the product of the number of teeth in the boss roller wheel, stud wheel and spindle shaft bevels, and then divide by the product of the teeth in the spur wheel on the spindle shaft, the pinion on the spindle, and the circumference of the boss roller in inches. We thus get a constant number of $\frac{102 \times 64 \times 28}{44 \times 19 \times 4 \cdot 4} = 49 \cdot 7$, which when divided by 1·46 turns per inch, gives 34 as the required twist pinion.

Bobbin Winding.—We will next consider the means by which this comparatively weak rove is built upon the bobbin in a regular manner without strain. This can only be done by giving the bobbin a positive motion by means of gearing. It is obvious that the winding may be done in two ways, either by running the flyer quicker than the bobbin or by running the bobbin quicker than the flyer. The former plan is almost universal in roving frames for flax, hemp, and jute. Advantages are claimed for both. The chief reason why the "bobbin lead" has not been adopted in this class of roving frame is, that with the ordinary "sun and planet" motion, fig. 52, which is almost universally employed, the crown wheel G must be driven in an opposite direction to the frame shaft, thus increasing friction, and also at a higher speed, which means power. The benefits claimed for it are, that when the roving frame starts, the spindles often commence to revolve before the bobbin; in this case, if the flyer leads, a stretch is given to the rove, but if the bobbin leads, the flyer merely winds a little

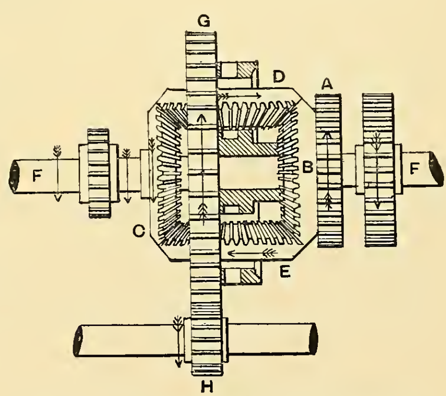


FIG. 52.—Houldsworth's differential motion for the roving frame.

off. In the former case, too, if the end breaks, the bobbin, continuing to revolve, unwinds rove off itself. In the latter case, the end is lapped on and kept in position. Whichever method is adopted the bobbin varies in speed, in the former case running slower, and in the latter case quicker, when empty than when full.

We have shown that the speed of the bobbin bears a fixed ratio to that of the socket wheel which runs loose upon the frame shaft. It is the speed of this socket wheel, then, which is changed during the progress of the doff.

It is said that in the early days of flax spinning a cone drive alone was used to give the bobbin a varying speed. A friction drive, and especially that of a cone belt, could not be depended upon to drive the bobbin ; besides, it is not fine enough to give the small changes of speed

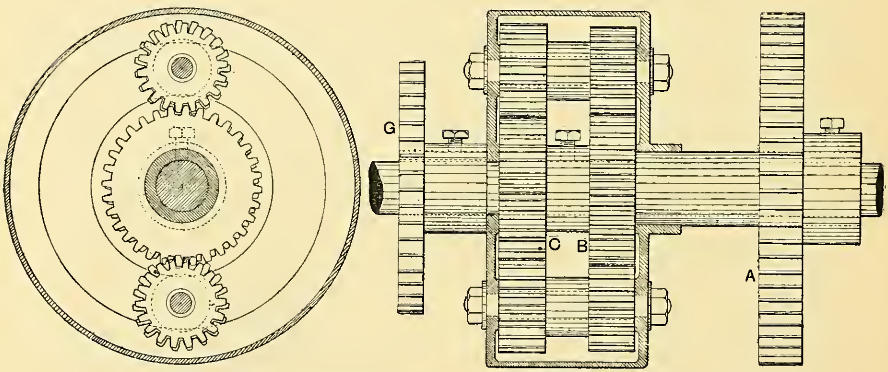


FIG. 53.—Differential motion as applied to Mackie's roving frame.

necessary. The differential motion is now employed, the original of which was invented by Joseph Raynor in 1813. This motion, as improved by Houldsworth (fig. 52), is still in use, although ingenious modifications are employed, such, for instance, as that shown in fig. 53. The improvements have as their objects the diminution of friction, and consequently the amount of work to be done by the unsatisfactory, but necessary, drive of the cone belt, expansion pulley, or disc and scroll.

The differential wheels as Houldsworth made them (see fig 52), consist in a large wheel G, say 14 inches in diameter, having one or two bevel wheels, D and E, working on studs set at right angles to its axis and placed between the latter and the rim of the wheel. The second bevel wheel usually employed is really unnecessary, but acts as a balance to the wheel, and may be replaced by a weight. The large wheel G revolves loosely upon the frame shaft F F, carrying round with it the wheels which it contains. Upon either side of it, and upon the frame shaft, are two bevel wheels B and C, of equal diameter and pitch to those in the differential wheel. One of these, C, is fast upon the shaft. The other, B, is loose and compounded with the socket wheel A, before referred to, which drives the bobbins.

If this combination be carefully studied, it will be seen that if the crown or differential wheel be held at rest, the bevel wheels which it contains will merely serve as carriers to transmit the motion unchanged, except as regards direction to the socket. The socket wheel A then always travels in an opposite direction to the frame shaft when at work. If the frame shaft be at rest and we turn the crown wheel G by hand in the same direction as that in which the former usually turns, we will find that, since the two bevels upon the shaft are the same size, the loose one will make two revolutions for each made by the crown wheel, one revolution being due to the motion imparted to the intermediate bevel by being carried round the fixed bevel, and the other to the crown wheel carrying round the loose bevel with it in consequence of the reaction of its teeth upon those of the intermediate bevel. The socket wheel A in this case revolves in the same direction as the crown wheel. If the crown wheel G be turned in the opposite direction, the socket wheel A will still make two revolutions for each one made by the former and in the same direction. The motion of the socket wheel A is then, when at work, the resultant of two velocities—one imparted to it by the frame shaft and the other by the crown wheel. The former is equal to that of the frame shaft, but in an opposite direction; the latter is equal to twice that of the crown wheel and in the same direction. We will call the direction of motion of the frame shaft positive, and designate it by the + sign, and the opposite direction negative, designating it by the − sign.

Let the velocity of the frame shaft be called a and the velocity of the crown wheel b. The resultant velocity of the socket A is then $a \pm 2b$, according to whether the crown wheel is run in an opposite direction or in a similar direction to the frame shaft. In the former case the socket runs at a higher speed than the frame shaft, and the bobbin leads the flyer; in the latter the socket revolves slower than the frame shaft and the flyer leads.

The object of the improved differential motion shown in fig. 53 is to reduce friction and the amount of work to be done by the cone belt or its substitute. In this piece of mechanism the crown wheel is replaced by a circular metal box, compounded with a socket wheel G, both revolving upon the frame shaft and driven by gearing from the lower cone. Inside the box, near its periphery and between and at right angles to its sides, two studs are fixed, which carry double pinions revolving freely upon them. One of each pair, those nearer the geared end of the box, work into a spur wheel B, fast upon the frame shaft and which corresponds with Houldsworth's "sun wheel." The other two pinions gear with a spur wheel C compounded with the socket wheel G running loose upon the shaft, which socket wheel drives the bobbins. If the combination be studied, it will be seen that it is but a modification of the same old principle of epicyclic gear. If the box be at rest, motion, unchanged in direction, will be transmitted to the socket wheel from the wheel upon the frame shaft through the carrier pinions. If the number of teeth and pitch of the "sun" wheel, spur wheel on the socket and the stud carrier pinions composing the pair be the same, each to each, the socket wheel will have the same velocity as the frame shaft, the "box" being at rest. These wheels and pinions are made of different diameter and pitches, however, to produce a difference in speed.

If the box be moved round at the same time and in the same direction as the frame shaft, the driving "power" of the "sun" or fast wheel B will be diminished by an amount varying directly as the speed of the box, which thus serves the same purpose as the crown wheel in Houldsworth's motion. The "box" has a natural tendency to be carried round by the revolutions of the fast or "sun" wheel, so that when this motion is used the duty of the cone belt is not that of a driver, but rather of a drag or governor to retard and regulate the speed of the box. Another advantage of this combination is reduction in friction, as the socket wheel and sleeve revolve in the same direction as the frame shaft, which is not the case with the older motion. Minor advantages are the substitution of spur for bevel gear, and the fact that most of the gearing is enclosed in the practically dust-proof box.

It is by putting the crown wheel or "box" respectively in motion, then, that we are able to obtain a difference in speed between the bobbin and the flyer. This difference in speed, and consequently the speed of the crown wheel or of the "box," varies inversely as the diameter of the bobbin barrel as it fills. When the bobbin leads, the bobbins must revolve comparatively quickly when empty, gradually diminishing in speed as the bobbin fills. When the flyer leads, the inverse of this takes place. There are at least three different ways of driving the crown wheel or the "box" and changing the difference in speed of the bobbin and flyer proportionate to the diameter of the bobbin. The one in most general use is by means of hyperbolic cones. The larger diameter of the cones is usually about 6 inches and the smaller 3 inches, their length being about 36 inches. It will be noticed that in a properly constructed pair of cones the slope from the small to the large end is not a straight line, in one being slightly rounded and in the other correspondingly hollowed. This curve is what is known as a hyperbola, and is the only one with which the speed of one being constant, the speed of the other and, consequently, that of the crown wheel and lag or gain of bobbin may be increased or diminished by a given shift or belt, by amounts proportionate to the increasing diameter of the bobbin barrel. It will be noticed that the change in speed of the bobbins is much more rapid when it is comparatively empty than when full, as then the constant increase bears a greater ratio to the diameter of the barrel than when the bobbin is larger.

The diameter of a properly shaped cone at any point may be found by multiplying the length of the cone in inches by the greater diameter, and dividing by the length of the cone in inches plus the distance of the given point from the large end of the cone. Thus the diameter of the cone just mentioned, at a point ten inches from its large end, is $\frac{36 \times 6}{36 + 10} = \frac{216}{46} = 4{\cdot}7$ inches.

The diameter of the complementary cone at a similar distance from the small end is $(6 + 3 \text{ inches}) - 4{\cdot}7 \text{ inches} = 4{\cdot}3$ inches. These cones are placed horizontally, one underneath the other, their centres being distant about 3 feet. The upper one has a wheel upon the extremity of its shaft, which is identical with one of those intermediates mentioned in our twist calculation as lying between the twist change wheel and the boss roller. The velocity of this cone is therefore constant for any given twist wheel. Motion is communicated to the lower cone by means of a belt, which can be shifted the entire length of the cones by means of a fork attached to a rack, actuated by the escapement of the index or ratchet wheel. When replacing the cone belt by a new one, the thickness should be as nearly as possible the same, since the thickness of the belt affects the relative speed of the cones to an appreciable extent. To be exact, the thickness of the belt should be added to the diameters of both cones. The small end of the lower cone can be raised by means of a rack and hand wheel, when it is required to shift the belt back to its starting-point to commence a new set of bobbins. When working, the weight of the lower cone is sustained by the belt, thus maintaining the tension of the latter. Upon the large and fixed end of the lower cone is a small pinion, which communicates the varying motion of the lower cone to the crown wheel through a small countershaft. The variable velocity of the lower cone is also utilised in the following manner to give to the builder the variable speed rendered necessary by the increasing diameter of the bobbin. A small pinion, on the end of the small counter or crown shaft above referred to, drives another shaft through a wheel keyed upon its end. The other extremity of this latter shaft has a small lateral movement controlled by a spring "rat-trap" motion, actuated by the upward and downward motion of the builder. This rat-trap or strike motion is shown in fig. 54. The small lateral movement which it imparts to the shaft C is sufficient to put the wheel, shown on the end of that shaft, alternately into gear with one or other of two spur pinions shown upon either side of it. These two pinions are compounded with stud wheels, which are themselves in gear, as shown, so that their direction of rotation depends upon which pinion is in gear with the driver.

In fig. 54, the catch A to the right is shown holding the tumbler bracket B with the pinion on the end of the movable shaft C, in gear with the wheels to the left.. When this catch is relieved by the descending builder, depressing the arm of the catch bracket D, the bracket B turns on its centre, bringing the wheel and shaft C into gear with the wheel to the right, and in this way changes the direction of rotation of the wheel C, and the motion of the builder when the latter reaches either extremity of its traverse. From either of the strike motion wheels, motion, in one direction or the other, is conveyed, through a changeable builder pinion and other intermediates, to a shaft running the whole length of the frame behind and below the builder. This shaft has pinions keyed upon it at frequent intervals. These pinions engage with vertical racks attached to the builder, which is thus given a reciprocating vertical motion, being guided by vertical slides and balanced by weights supported by chains.

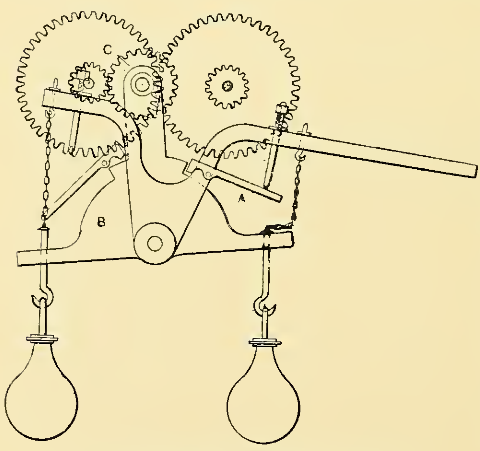


Fig. 54.—Rat-trap or strike motion for cone roving frame.

Each make of flax, hemp and jute machinery has its own special method of giving a variable motion to the bobbin and builder. Two use the cones just described, two the expansion pulley A, fig. 55, and one the disc and scroll mechanism, fig. 57. All of these have the same object—namely, to *increase* the speed of the bobbin as it fills by *diminishing* the speed of the differential or crown wheel B which turns in the same direction as the frame shaft C in a manner and in a proportion already discussed.

Combe's Expansion Pulley and Quick Change Motion.—The expansion pulley shown at A and A′ in fig. 55 is in two halves. One, the half A, is fast upon its shaft, while the other is free to move inwards and intersect the other as it is constrained to do so by being gradually raised and at the same time pressed against a triangular slide. The raising of the expansion pulley around the shaft D as a centre compensates exactly for its increase in diameter, and keeps the driving band E at a constant tension. F is a grooved rim or rope pulley fast upon the boss or drawing roller of the frame. The expansion pulley is raised by means of a quadrant which supports the end A. The angle plate which controls the intersection of the two sides of the pulley is generally made with a bevel of one inch per inch perpendicular. The angle of the sides of the pulley is generally such that, for every inch the pulley is pushed in, its diameter is increased by $1\frac{1}{4}$ inches. Each shift of the quadrant and of the pulley is effected, when the builder has reached the extremity of its travel at either end, by the escapement of a ratchet wheel, the catch retaining which is released by the motion of the builder. The speed of the bobbin and builder is thus regulated for the succeeding layer of rove. Fig. 55 also shows the most

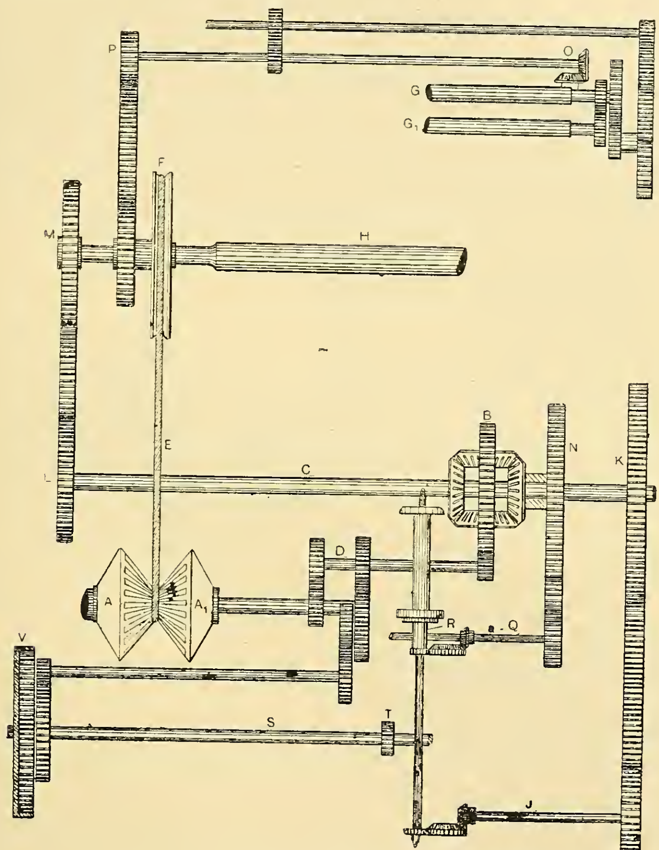


Fig. 55.—Combe's expansion pulley and gearing.

important parts of the roving frame. G and G_1 are the feed rollers, and H the boss or drawing roller. The space between these two sets of rollers is occupied by the fallers and gills, which are driven forward by screws actuated by bevel gearing similar to O. The draft gearing is also shown, P being the draft pinion, by increasing or diminishing the size of which the speed of the feed rollers is reduced or augmented, and the draft lengthened or shortened. The twist gearing is shown between the boss roller and the spindle. The speed of the spindles is constant for any given speed wheel K. More or less twist is given to the rove by diminishing or increasing the speed of the boss roller H, by putting on a smaller or larger twist change wheel L. The gearing for driving the bobbin from the socket wheel N, through the bobbin shaft Q, bevels and carrier R, is also clearly shown. S is the builder shaft upon which pinions T drive the builder up and down by means of racks, the reciprocating motion being obtained in the case of Combe's frame by the use of the change motion shown in detail in fig. 56. In that figure A is a wheel which has a pinion keyed upon its pap and gearing internally, with the mangle wheel V, fig. 55. The wheel A is driven alternately by one or other of the two small pinions E and C, which gear into each other and alternately with the wheel A. The pinion E is upon the end of a movable shaft driven from the differential motion. The pinion C works loose upon a stud fixed in the arm D.

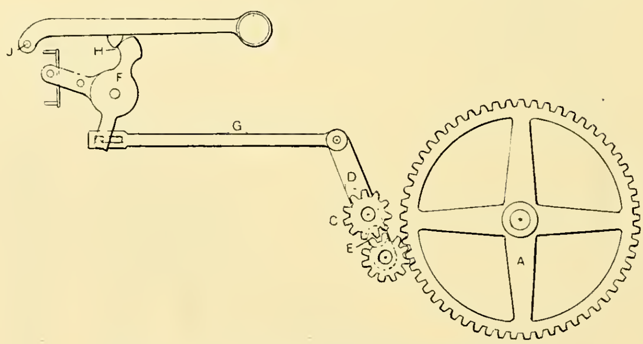


FIG. 56.—Combe's quick change builder motion.

This arm D is moved backwards and forwards, putting the pinions E and C in and out of gear by means of the connecting rod G, communicating motion from the piece F, which is turned upon its centre by the up-and-down motion of the builder. A quick and effective change is effected by means of the wedge-shaped pieces H, the upper one forming part of a weighted lever centred in J. The apex of the upper wedge should be vertically above the centre of F, so that the piece F, being symmetrically designed and turned in a negative sense by the falling builder, quickly escapes as the apices pass and the pinion C is forced into gear with the wheel A, while the pinion E is disengaged and the wheel A and the builder are driven in the opposite direction.

Fairbairn's Disc and Scroll Mechanism.—Fairbairn's disc and scroll mechanism is shown in fig. 57. A is a friction bowl sliding upon a feather upon a shaft which, through the gearing shown, regulates the speed of the differential wheel B. The bowl A and the shaft upon which it slides receive motion by frictional contact with two horizontal discs D D upon a vertical shaft E.

The diameter of the discs is usually 20 inches. The lower one only is keyed upon the shaft E. The upper one works upon a long sleeve which carries a mitre wheel on its upper end. The vertical shaft or spindle E projects through the sleeve F and has another mitre wheel, G, keyed upon its upper extremity. The vertical shaft E and discs D D receive their motion, through intermediate gearing, from the twist wheel. This motion is a regular one, and the change in speed of the crown wheel is effected by shifting the friction bowl from the periphery towards the centre of the

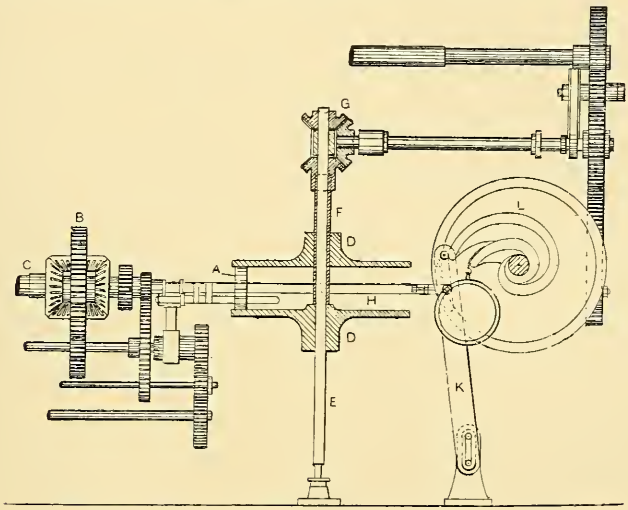


Fig. 57.—Fairbairn's disc and scroll mechanism for the flax, hemp and jute roving frame.

discs by means of the guide rods H, the lever K centred at its base, and the scroll L. The other parts of the mechanism are similar to those already described.

Fraser's Patent Spiral Roving Frame.—In Fraser's patent spiral roving frame, shown in fig. 51, expansion pulleys or cones and mangle wheel are employed. The Vee leather band, used to drive the expansion cones or pulleys, is arranged so that the slack is taken up automatically and the strain on the band maintained light and uniform throughout the filling of the bobbin. It will be noticed that in this frame, which is intended for heavy work, leather-covered metal pressing rollers are employed, and also that the spindle tops are supported and steadied by cap plates which are hinged and may be raised for doffing.

Power of the Crown Wheel.—Referring to pages 136 and 148, it will be seen how the speed of the spindles is obtained, also that of the bobbin, depending upon the speed of the socket wheel forming part of the differential motion. In conjunction with the following figures and the explanation of the motion on pages 141 and 137, we have shown that the "power" of Houldsworth's crown or differential wheel, fig. 52, is two, or that when the flyer leads, the socket wheel loses two revolutions for each one made by the crown wheel, also that in the frame we have taken as an example, the bobbins make 2·8 revolutions for one of the socket. Hence it will be seen that the bobbin lags behind the spindle or loses $2·8 \times 2 = 5·6$ revolutions for each turn made by the crown wheel. Where a equals the speed of the frame shaft and b of the crown wheel, the speed of the bobbin at any moment is $2·8a - 5·6b$ or $2·8\ (a - 2b)$. If N represent the revolutions of the boss roller per minute, $1\frac{1}{2}$ inches its diameter, and d the diameter of the bobbin at any given moment, the requisite lagging of the bobbin at that moment equals $\frac{1\frac{1}{2} \text{ inch} \times 3·1416 \times N}{d \times 3·1416}$ or $\frac{1\frac{1}{2}N}{d}$, or, as above, $5·6b$. $\frac{1\frac{1}{2}N}{d}$ then $= 5·6\ b$, or $b = \frac{1·5N}{5·6\ d}$; b thus varies inversely as d. If a pinion of 16 teeth upon the lower cone drives a crown shaft wheel of 66 teeth, and a crown driver of 26 teeth drives a crown or differential wheel of 105 teeth, the boss roller wheel having at the same time 102 teeth, and the upper cone wheel 40 teeth, the working diameter of the upper cone at that moment being x, h denoting the speed of the lower cone, and the sum of the diameters of the cones being 6 inches + 3 inches = 9 inches, $h = \frac{102 \times N \times x}{40 \times (9 - x)} = \frac{51 \times N \times x}{20 \times (9 - x)}$, also $h = \frac{b \times 105 \times 66}{26 \times 16}$.

Substituting the value of b, as found above, we get $h = \frac{1·5N}{5·6\ d} \times \frac{105 \times 33}{26 \times 8}$ $= \frac{742·5N}{166·4\ d}$, which is the speed of the lower cone when the diameter of the bobbin barrel equals d. The constant velocity of the upper cone is $\frac{102 \times N}{40}$. Its surface speed at diameter x equals the surface speed of the lower cone at diameter $9 - x$, or $\frac{102 \times N \times x}{40} = \frac{742·5 \times N \times (9 - x)}{166·4\ d}$. Dividing across by N we get $\frac{102 \times x}{40} = \frac{742·5 \times (9 - x)}{166·4\ d}$. Then clearing of fractions, $16972·8\ xd = 267300 - 29700\ x$, and $x\ (16972·8\ d + 29700) = 267300$ and $x = \frac{267300}{16972·8\ d + 29700}$. Substituting the value of d, which at the start of the set equals the diameter of the bare barrel, or $1\frac{3}{16}$ inch, we get $x = 5·36$ inches, which is the working diameter of the upper cone at the start. The working diameter of the lower cone at the start equals $9 - x$, or $9 - 5·36 = 3·64$ inches. On the frame and with this gearing, the working diameter of the cones at any stage of the doff may be found by substituting the actual diameter of the bobbin, at that moment, for d in the equation, $x = \frac{267300}{16972 \cdot 8\, d + 29700}$. Taking the rove we instanced previously, 320 yards per ounce, and built 26 rows per inch in length and 90 rows per inch in depth, when 90 rows have been put on, the bobbin will be 2 inches greater in diameter, or $3\frac{3}{16}$ inches. If we substitute this for d in the above equation, we get 3·19 inches as the working diameter of the upper cone when 90 rows have been put on. The distance in inches y of any diameter D from the large end of these cones may be obtained from the equation as on page 143, $D = \frac{36 \times 6}{36 + y}$. Substituting 5·36 and 3·19 separately for D in this equation, we find that the working diameter of the upper cone at the start of the doff is 4·3 inches from the large end of the cone, and that when 90 shifts have been made, it is 31·7 inches from the large end. In 90 shifts the cone belt has thus travelled $31 \cdot 7 - 4 \cdot 3 = 27 \cdot 4$ inches, or $\frac{27 \cdot 4}{90} = \frac{3}{10}$ inch per shift. The pitch of the teeth in the rack being $\frac{1}{3}$ inch, and the rack wheel having 76 teeth, this wheel makes $\frac{\cdot 3}{76 \times \cdot 33} = \frac{1}{84}$ of a revolution per shift. Therefore a 42 index wheel, compounded with the rack wheel and shifting half a tooth every rise and fall of the builder, is required to build such a weight of rove in this manner.

We have shown that the difference in speed of the bobbin and flyer equals 5·6 times the speed of the crown wheel, therefore 5·6 rows in length of traverse are put on for each revolution of the crown wheel. As there are 26 rows per inch in the build we have selected, this means a rise or fall in the builder of $\frac{5 \cdot 6}{26}$ inches for each revolution of the crown wheel. The pitch of teeth in the builder rack being $\frac{1}{2}$ inch, and the rack pinions on the traverse shaft having each 22 teeth, the latter shaft makes $\frac{5 \cdot 6 \times 2}{26 \times 22}$ of a revolution for each turn of the crown wheel. Upon the end of the traverse shaft is a wheel of 96 teeth working into a stud pinion of 14 teeth, compounded with a stud wheel of 86 teeth which gears with the builder pinion. This stud wheel thus makes $\frac{5 \cdot 6 \times 2 \times 96}{26 \times 22 \times 14} = \frac{19 \cdot 2}{143}$ of a revolution for each turn of the crown wheel. Beginning at the other end of the train now, the crown wheel has 105 teeth and is driven by a pinion of 26 teeth upon the crown shaft, upon the end of which another pinion of 12 teeth drives the movable shaft through a wheel of 36 teeth. Upon the other end of this latter shaft a wheel of 24 teeth drives a socket wheel of 40 teeth, compounded with which is the builder pinion. The builder pinion thus makes $\frac{1 \times 105 \times 12 \times 24}{26 \times 36 \times 40} = \frac{21}{26}$ of a revolution for one of the crown wheel. There being 86 teeth in the stud wheel which gears with the builder pinion, and which makes, as we have just shown, $\frac{19 \cdot 2}{143}$ of a revolution in the same time, the number of teeth in the builder pinion must be $\frac{86 \times 19 \cdot 2 \times 26}{143 \times 21} = 14$ teeth.

Thus, upon this frame a 42 index wheel and a 14 builder pinion are required to build this rove in the manner described.

The index and builder pinion for a frame other than the cone frame may be found in a somewhat similar manner, and the latter in every case directly from the crown wheel. In the disc and scroll frame, if the scroll and index wheel make a complete revolution to fill the bobbin, the number of teeth in the index wheel equals the number of rows in depth upon the bobbin when one tooth is slipped every change. When only one half tooth is slipped, the number of teeth equals one half the number of rows in depth upon the bobbin under the same conditions. When a smaller headed bobbin is used, and the full throw of the scroll not required, the number of teeth in the index wheel will be just the same as that required to fill the larger bobbin, since the wheel only makes a partial revolution.

In the expansion pulley frame, the diameter of the expansion pulley is directly as the diameter of the bobbin. Suppose we find that, when the bobbin is 2 inches in diameter, the expansion pulley has a diameter of $4\frac{3}{4}$ inches. If the rove be 40 rows per inch in depth, when 40 changes have been made, the diameter of the bobbin will be 4 inches and that of the expansion pulley $9\frac{1}{2}$ inches. If the construction of the bevel plate and pulley be such that 1 inch of rise in the pulley produces 1 inch of intersection, and 1 inch of intersection an increase of $1\frac{1}{4}$ inches in the diameter of the pulley, a rise of 3·8 inches is required to increase the diameter from $4\frac{3}{4}$ to $9\frac{1}{2}$ inches. This was done, we said, in 40 shifts, which means a rise of $\frac{3 \cdot 8}{40} = \cdot 095$ inch per shift. If the long and short arms of the quadrant lever which raises the pulley be respectively $14\frac{3}{4}$ inches and 6 inches, a point on the pitch circle of the rack will move through $\frac{\cdot 095 \times 14 \cdot 75}{6} = \cdot 23$ inch per shift, which, the pitch of the teeth of the wheel being $\frac{3}{8}$ inch, equals $\frac{\cdot 23}{\cdot 375} = \cdot 61$ tooth. If the pinion on the index spindle working into the rack has 24 teeth, it must make $\frac{\cdot 61}{24} = \frac{1}{40}$ revolution per shift. The index wheel, being upon the same spindle, also makes $\frac{1}{40}$ revolution per shift, and consequently must have 20 teeth if one half tooth is slipped at each "change."

In these calculations the author has neglected such factors as the contraction of the rove by twist, the thickness of the cone belt, and the length of one lap of rove. The latter is not, strictly speaking, the diameter of the bobbin at the moment multiplied at 3·1416, but the perimeter of an ellipse, the minor axis of which is the actual diameter of the bobbin, the major axis depending upon the pitch of the spirally wound laps or upon the rows per inch in the length of the traverse.

Practical Changing.—In practice the correct index wheel and builder pinion to start a new roving frame are usually arrived at by experience, and by comparison with a similar frame already working. When changing from one weight of rove to another, they are changed in proportion to the square root of the yards per ounce of rove, which is always inversely proportional to the weight of the sett and to the number of doublings, and directly proportional to the drafts.

If, for instance, we have a frame making rove 150 yards per ounce and building it correctly with a 35 index wheel, and we have made the sett lighter by an amount which should bring out rove 200 yards per ounce—to find the index wheel necessary to build this lighter rove in a similar manner, we must first square the number of teeth in the old index wheel, then multiply by the new weight of rove, then divide by the old, and finally extract the square root of the quotient thus:—
$\sqrt{\frac{35^2 \times 200}{150}} = \sqrt{\frac{1225 \times 200}{150}} = \sqrt{1633} = 40.$ An easier method, and nearly accurate, is to work by proportion; add the old index to the result and halve the total thus obtained. As follows:— 150 : 200 : : 35 : 47, $\frac{47 + 35}{2} = 41.$ The twist required being *directly* proportional to the square root of the number of yards per ounce of the rove, and the number of teeth in the twist pinion being inversely proportional to the twist it produces, the twist pinion may be found in a similar manner by squaring the number of teeth in the old twist pinion, multiplying by the number of yards per ounce in the old rove, dividing by the number of yards per ounce in the new rove, and extracting the square root of the result. Thus, if a 55 twist pinion is required for rove 150 yards per ounce, what twist pinion will be required for rove 200 yards per ounce? Evidently a smaller pinion or $\sqrt{\frac{55^2 \times 150}{200}} = \sqrt{\frac{3025 \times 150}{200}} = \sqrt{2269} = 48$ nearly; or again, as before, work by proportion, add the old twist pinion to the result and halve the sum thus obtained, thus:—200 : 150 : : 55 : 41 and $\frac{41 + 55}{2} = 48.$

Starting the Frame.—To start a roving frame, the ends are brought out through the delivery roller, slightly twisted by hand, passed through the eye in the head of the flyer, down the hollow leg, through the twizzle at the end and wrapped in the proper direction around the barrel of the empty bobbin. The differential motion is run back to its starting-point; that is to say, if a cone frame, the bottom cone is raised by the hand wheel and rack provided for the purpose and the cone belt screwed back to its starting position on the cone by means of another hand wheel. If it be an expansion pulley frame, the pulley is screwed down to its small diameter, and if a disc and scroll frame, the friction bowl is pulled back near the edge of the discs, the correct starting-point being marked and fixed by means of an adjustable stop. The winding on should be as slack as possible at the start in order to avoid strained rove and to ensure the rove winding off to the very end. When an index wheel has been changed, care must be taken that while one pawl holds the index, the other is exactly in the centre of a tooth so that exactly a half tooth may be taken each time.

Rove Stock.—A rove stock of eight or ten bobbins of rove per spinning spindle should be kept and suitable bins provided in a cool and shady place near the preparing room for storing them prior to their removal to the spinning room. A principle very frequently lost sight of in practice is that all vegetable fibres are improved in spinning quality by being allowed to remain lying for a short time in a suitable place after every stage of their manufacture. Scarcity of rove necessitating its hurried removal from the roving frame to the spinning room should be avoided, and may be sometimes cured by providing every roving frame with a counter showing the number of revolutions of, say, the boss roller, and paying the rover a bonus upon results as regards production.

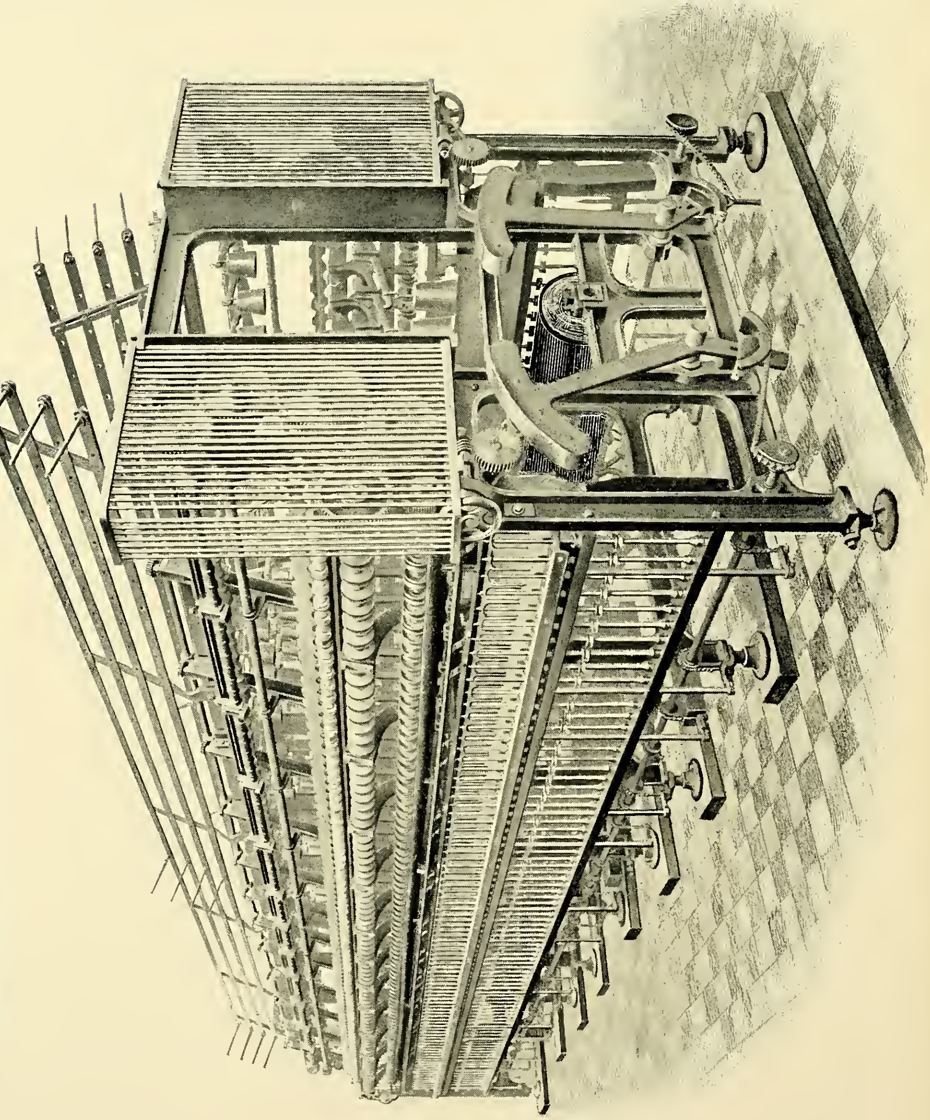


FIG. 58.—Double dry spinning frame for shoe threads of flax or hemp, as made by Messrs J. Mackie & Sons, Ltd., Belfast.

CHAPTER XII.

DRY AND DEMI-SEC SPINNING OF FLAX, HEMP, JUTE AND RAMIE.

The Dry Spinning Frame.—Although yarn as fine as 16's lea linen and weighing 4800 yards per lb. may be spun on the finest of the gill spinning frames which we have described in Chapter X., such a method of production is rare, and is only employed where a very level and superior yarn is required. Dry spinning frames, then, such as are shown in figs. 58 and 59, are used for materials such as jute (which cannot be spun very fine), for coarse flax tows where a bulky thread for filling purposes is required, or for superior flax and hemp yarns of medium counts when the maximum strength is sought for, such being obtained by allowing the ultimate fibres to remain joined together in a long length. A long reach frame of somewhat similar construction is also required for ramie or rhea, the ultimate fibres of which are long and strong.

Fig. 58 shows a good form of dry spinning frame specially adapted for spinning superior yarns, such as shoe threads, from flax and hemp.

Fig. 59 shows, in section and detail, a frame constructed upon the same principle, but having several special features which we will describe later on.

In the dry spinning frame, the bobbins of rove, produced as described in the last chapter, are placed upon stationary pins, seen in both figures and ranged above the feed rollers at such an inclination that the rove may be drawn off the bobbin at right angles with its axis.

The feed rollers are from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches in diameter, of steel and fluted 12 to 20 per inch of diameter. The drawing rollers are likewise of steel, their bosses being 3 to 5 inches in diameter and $\frac{3}{4}$ to $1\frac{1}{8}$ inch face. The face of the bosses is also scored or fluted to 16 to 24 per inch. The pressing rollers, usually of sycamore, about 8 inches in diameter and tapered to a narrow face, say $\frac{1}{4}$ inch broad, are placed behind the metal drawing roller, against which they are pressed by springs or by a lever and weight as clearly shown in fig. 59. In a jute dry spinning frame the reach or distance from centre to centre of the drawing and retaining rollers is usually 9 inches. For long line flax and hemp it must often be 18 inches, and is consequently often made adjustable. In the frame shown in fig. 58, for instance, the reach may be raised or lowered, by means of screws coupled to a shaft passing through the frame. In passing between the feed and drawing rollers, the rove is guided and controlled by a breast plate supplemented by bearing rollers if the reach is very long. The length of the reach being equal to that of the longest fibres, the breast plate may be made to take the place of gills in controlling the delivery of material to the drawing rollers. For the breast plate may be advanced or retired, either

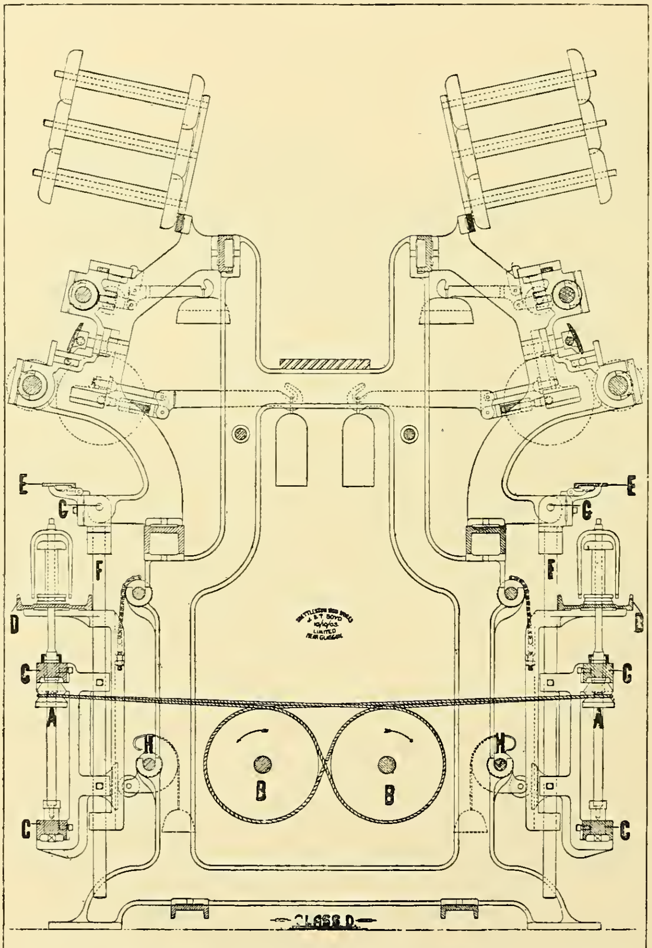


FIG. 59.—Boyd's patent swing rail dry spinning frame for hemp and jute.

partially or bodily, by means of adjusting screws, causing the rove which passes over it to be pressed against it with more or less tension, preventing the twist from running out of the rove and the short fibres from being gulped. The levelness of the yarn produced depends to a great extent upon the skilful regulation of the breast plate and bearing rollers. A small funnel-shaped tin conductor is used to guide the material to the narrow-faced drawing roller. The spindles, distant one from the other from 3 to

5 inches, are placed vertically in one row, the line of the spindle produced being slightly forward from the point of delivery, causing the end, while being twisted, to bear upon the eye of the thread plate E, fig. 59, which steadies it and prevents ballooning.

The flyers are screwed upon the spindle tops. The ends are lapped once or twice around the leg, and pass, through a semicircular nick in its flattened end, to the bobbin which runs loose upon the spindle. The bobbins have heads $1\frac{1}{2}$ to 3 inches in diameter and a 3 to 5 inch traverse according to the pitch of the frame. The base of the bobbin is grooved for the drag band, which, attached to the back of the builder, touches the bobbin base and passes over the nicked front edge of the builder, tension being maintained by a drag weight attached to the end of the cord. The drag upon the bobbin must be sufficient to put the requisite tension upon the end to prevent ballooning, since winding on is done by the flyer, which runs quicker than the bobbin, the latter being dragged round by the yarn. The difference in speed between flyer and bobbin is just sufficient to take up the yarn as spun, and naturally varies according to the diameter of the bobbin. The bobbin rests upon the builder, which is given an up-and-down motion by means of poker rods, chains, and a builder shaft, which is given a reciprocating motion by means of a heart wheel or a quadrant motion, such as is shown in fig. 58.

The spindles rest in footsteps set in the step-rail, which extends the whole length of the frame. They turn in brass collars set in the neck rail, and are caused to revolve at a speed of from 2000 to 4000 revolutions per minute by cords or tapes passing around a tin cylinder B and a wharve fixed upon the spindle.

A rove traverse motion above the feed rollers should always be provided to increase the life of both feed and drawing rollers.

The creel of the frame shown in fig. 58 is adapted for spinning double rove, a method of spinning which, by increasing the doublings twofold, adds considerably to the levelness of the yarn produced. The spinning of the double rove, however, of course increases the cost of production, since more roving spindles and complementary preparings will be required.

Swing Rail Dry Spinning Frame.—The special feature to be noticed in connection with the dry spinning frame, fig. 59, is the spindle driving. The spindles A are driven, each with a separate band, from a double row of cylinders B. This ensures the driving of the spindles on both sides of the frame in exactly similar conditions (which is impossible with a single cylinder as used in the ordinary frame). The spindle rails C, the lifter rails D, and the thread plates E are made in short sections of twelve spindles each. Instead of fixing the rails to the framing, each set is carried on a pair of swinging pokers F, centred close to the thread board on a strong stud G on the main framing, so that they are free to swing from and towards the cylinder for the purpose of tensioning the bands. A pair of weighted levers, H, are employed to give the necessary pressure of the spindle rails and spindles outwards against the bands. In this way whatever tension is decided upon can with exactness be kept on each band. Thus all irregularities in the driving, caused by a damp or dry atmosphere affecting the bands, is overcome, and a minimum driving power can be fixed and relied upon. When a new band is put upon a spindle it is instantly stretched to the length of the bands on the other eleven spindles on the rail, as it receives the whole outward pressure applicable to twelve spindles.

By employing two cylinders B B, the down thrust of the spindles into their footsteps is prevented, thus saving loss of power and wear of spindle. The pull of the band on one side counteracts the pull from the other side, thus taking the strain (200 lbs. or more) off each cylinder.

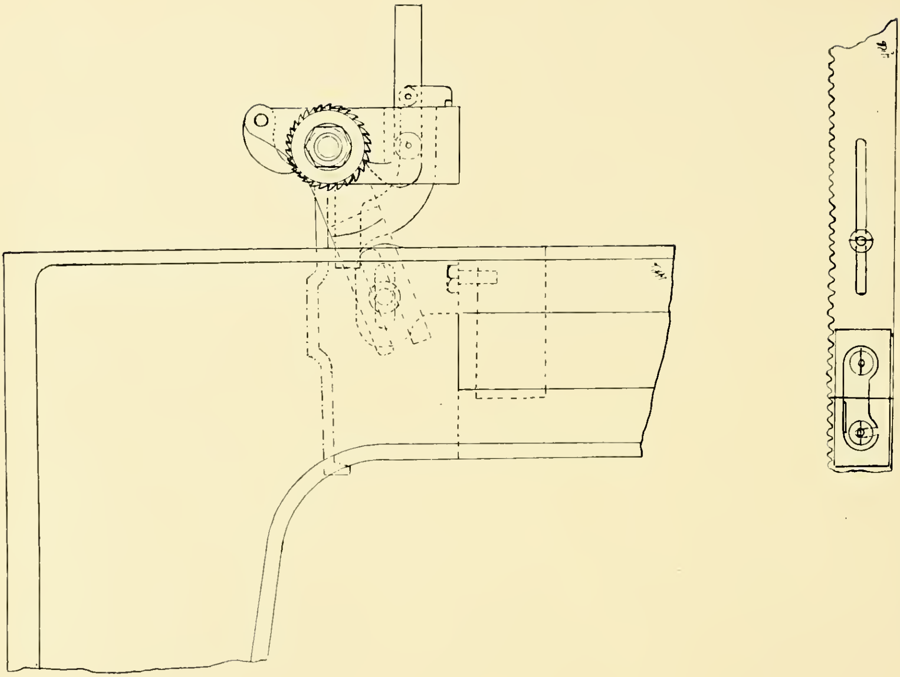
In addition to the advantage of regularity of spindle driving, the suspended swing rail ensures absence of vibration in the spindle and thus causes the tension upon the end to be much more regular.

The spindles are fitted with patent self-oiling necks which require oiling only once a month instead of at least twice per day, as in the ordinary frame.

It is claimed that, by the swing-rail arrangement of spindle driving, the bands are kept at one tension even in damp weather, and that the variation in their driving power does not exceed 5 to 10 per cent. throughout the whole of the spindles in a frame. Actual electric motor tests show that upon an ordinary frame of 4-inch pitch, one horse power drives 12·3 spindles at 2500 revolutions per minute, while with a swing-rail frame of similar pitch, one horse power drives 20·6 spindles at approximately the same speed.

Particulars of Dry Spinning Frames for Jute.—The following particulars of dimensions and speeds of dry spinning frames are in conformity with the ordinary practice of the jute spinning trade :—

Pitch of Frame.	$3\frac{3}{4}$	4	$4\frac{1}{2}$	5
Bosses per head, ...	8	8	6	6
Diameter of feed roller in inches, . . .	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$
Flutes per inch diameter of feed roller, . .	20	20	20	16.
Diameter of drawing roller in inches, . .	4	$4\frac{1}{2}$	$4\frac{1}{2}$	5
Flutes per inch diameter of drawing roller, .	16	16	16	12
Width of face of drawing roller in inches, .	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$
Dimensions of bobbins in inches, . . .	$3\frac{3}{4} \times 2\frac{1}{4}$	$4 \times 2\frac{1}{2}$	$4\frac{1}{2} \times 2\frac{3}{4}$	5×3
Diameter of spindles in inches, . . .	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$
Diameter of wharve in inches, . . .	$1\frac{3}{4}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$
Diameter of cylinder in inches, . . .	10	10	10	10
Speed of cylinder, revolutions per minute, .	600	560	585	660
Speed of spindle, revolutions per minute, .	3000	2800	2600	2400
Turns per inch twist, ...	3 to 9	3 to 9	2 to 6	2 to 6
Reach in inches, ...	9	9	9	9
Drafts, ...	5 to 10	5 to 10	4 to 8	4 to 8



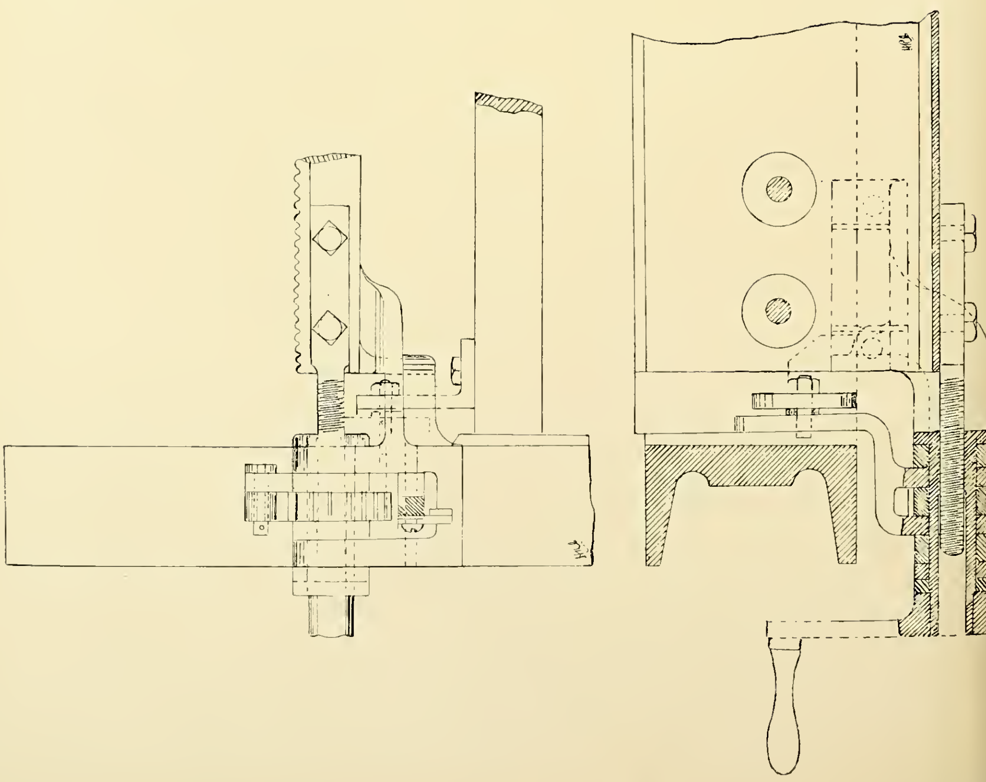


FIG. 60.—Carter's automatic bobbin dragging motion, as supplied by Mr Wm. Carter, 28 Waring Street, Belfast.

As in the gill spinning frame with fish-tail flyers and band or tape-driven spindles, the bobbins of the ordinary dry spinning frame are dragged by means of drag bands which are attached at the back of the builder, touch the base of the bobbin, and pass over a nicked builder strip, the tension being maintained by a drag weight attached to the free end of the band. The drag upon the bobbins is increased by shifting the bands further along on the nicked front builder strip, and in this way causing them to embrace a larger part of the base of the bobbin. This "tempering" of the drags requires some skill, and must be done regularly and uniformly as the bobbin fills and becomes heavier, and as the pull of the thread becomes more effective through acting upon the end of an increasing radial line.

When the bobbins are to be doffed, the drag bands must be set back, out of contact with the bobbin bases, and replaced in light contact with them when the frame is again started. Numerous automatic bobbin dragging motions have been tried and abandoned. In fig. 60 we give a view of the latest, which can be applied to gill, dry or wet spinning frame alike, and which is in use to-day, giving good results.

Carter's Automatic Bobbin Dragging Motion.—It will be seen that the upward motion of the builder is utilised to move round, by means of a ratchet and pawl, an internally threaded sleeve, which forms a nut working upon a screw attached to the front builder strip. The front nicked builder strip is made movable, while the screwed sleeve turns in a bracket attached to the builder, which bracket keeps it in position, so that in turning automatically it draws the nicked builder strip from right to left. As the builder falls the pawl slips over as many teeth of the ratchet wheel as it will move forward upon the return journey, the ratchet being kept from turning the while by the lower catch shown. The pawl may be caused to move forward more or less teeth each time, by shifting backwards or forwards the stud which is carried in a slotted bracket attached to the neck rail, and which works in an open-ended slot in the swinging arm which actuates the pawl. Thus for every two layers of yarn which are put upon the bobbin, the drag is slightly increased, so that the tension of the end remains regular from start to finish of the doff without any attention on the part of the spinner. The result is that there is no ballooning of the ends, that the yarn is built harder upon the bobbin, which consequently contains more yarn, and that the yarn is rounder and stronger, since the fibres lie closer together in consequence of having been twisted together under tension. The handle shown is provided to turn back the screwed sleeve, and in so doing carry back the nicked strip and put the drag bands out of contact with the bobbins for doffing. The handle is also used to wind the nicked strip forward again and bring the bands into contact with the bobbins before starting the frame with a fresh set of bobbins.

Draft Required.—The necesary spinning frame draft required to spin any given weight of yarn, depends upon the weight of rove from which it is to be spun. The weight of the rove may be designated in yards per ounce or in drams per 100 yards. In the former case, if the count of the yarn be expressed in leas or cuts of 300 yards per lb., the required draft is easily found by reducing both yarn and rove to the same denomination, *i.e.* yards per ounce, the draft required being in reality the ratio between the former and the latter. For instance, if we are given rove 30 yards per ounce, and are required to spin yarn 16 leas per lb., we find the yards per ounce in the yarn, *i.e.* $\frac{300 \times 16}{16} = 300$, and taking the ratio between the two, or dividing the greater by the less, we find that the requisite spinning draft is $\frac{300}{30} = 10$. This rule is much simplified by taking the yards per ounce in one lea yarn, or 18·75, as a constant number, which if multiplied by the lea required, gives the yards per ounce in that lea, which when divided by the yards per ounce in the rove gives the draft required. Taking the preceding example in this way, we find that the draft required is $\frac{18{\cdot}75 \times 16}{30} = 10$. If the weight in drams of 100 yards of rove be one of the particulars given, the draft may be found by dividing that weight by the weight in drams of a similar length of yarn. Thus, if 100 yards of rove weigh 60 drams and it is required to spin yarn 10 leas per lb., we must find the weight in drams of 100 yards of 10 lea yarn. We know that in 1 lb. or 256 drams of that yarn there are $10 \times 300 = 3000$ yards, therefore 100 yards of yarn weighs $\frac{256}{30} = 8{\cdot}53$ drams, and the draft required will be $\frac{60}{8{\cdot}53} = 7$. This rule may be simplified by taking 85·3, or the weight in drams of 100 yards of 1 lea yarn, as a constant number, and dividing it into the product of the weight of 100 yards of rove and the lea to be spun. Thus, taking the foregoing example in this way we again find the required draft to be $\frac{60 \times 10}{85{\cdot}3} = 7$.

Drafts may also be conveniently calculated by taking as bases the yards per ounce of rove and the weight of a bundle of yarn (60,000 yards) in lbs. The yards per ounce of yarn are 60,000 divided by the weight of a bundle in ounces, and the required draft the ratio between that result and the yards per ounce of rove. Thus the weight of a bundle of 8's being 25 lbs. and the rove from which it is spun 30 yards per ounce, the yards per ounce of yarn is $\frac{60{,}000}{25 \times 16} = 150$, and the required draft $\frac{150}{30} = 5$. In practice this rule is much simplified by making $\frac{60{,}000}{16} = 3750$, a constant number to be divided by the product of the weight of a bundle of yarn in lbs. and the yards per ounce of rove—thus $\frac{3750}{25 \times 30} = 5$ draft as before. Following the Scotch system, which is that almost always employed for jute yarns and in which the number of the yarn is denoted in lbs. per spyndle of 14,400 yards, the yards per ounce of yarn is easily found as before, by dividing the yards per spyndle by its weight in ounces, and then the draft required by dividing the yards per ounce of yarn by the yards per ounce of rove. Thus the yards per ounce of 3 lbs. yarn is $\frac{14,400}{3 \times 16} = 300$, to spin which yarn, on 10 of a draft, we will have to be supplied with rove weighing 30 yards per ounce. This calculation is simplified by taking $\frac{14,400}{16} = 900$ as a constant number and dividing it by the product of the lbs. per spyndle and the yards per ounce of rove—thus $\frac{900}{3 \times 30} = 10$ drafts.

The methods of calculation in Continental mills are often found to be identical with the foregoing, although in some cases the English avoirdupois weight is disappearing in favour of the metric system of weight, the base of which is the gramme. The English standard of length or yard and the bundle still remain, and probably will do so, as there is a considerable trade in yarn on both sides between Ireland and Scotland and the Continent. However, as the French metric system of yarn numbering is used to a small extent, we will explain it. Its base is a length of 1000 metres or one kilometre, and the number of the yarn is indicated by the number of kilometres required to weigh 500 grammes. For instance, 5000 metres of No. 5 yarn are required to weigh 500 grammes under the metric system. Since 300 yards equals 274·2 metres, and 1 lb. avoirdupois equals 453 grammes, No. 1 lea yarn Irish equals 3 metric, and No. 10 Irish equals No. 3 metric, and so on. It may be calculated that the weight of 50 metres of No. 1 yarn metric is 25 grammes, and that the weight of 50 metres of any other metric number is 25 grammes divided by that number. The draft required to spin any metric number is easily calculated by comparing the weight of 50 metres of rove with 50 metres of yarn. For instance, 50 meters of No. 5 metric yarn weighs $\frac{25}{5} = 5$ grammes, and if the rove weighs 45 grammes per 50 metres, a draft of $\frac{45}{5} - 9$ will be required to spin it.

If the English unit of length, or yard, be used in conjunction with the metric unit of weight or gramme, a convenient way of calculating the draft from the weight of rove is to divide the weight of 50 yards of rove in grammes by the weight in grammes of 50 yards of the yarn required. Fifty yards being one-sixth of 300 yards, or one lea, and there being 453 grammes per lb. avoirdupois, 50 yards of No. 1 lea Irish weighs $\frac{453}{6} = 75{\cdot}5$ grammes, and 50 yards of No. 10 lea Irish $\frac{75{\cdot}5}{10} = 7{\cdot}55$ grammes. If it be required to spin the latter lea from rove weighing 75 grammes per 50 yards, a draft of $\frac{75}{7{\cdot}5}$ or 10 will be necessary.

The weight of the rove may be conveniently expressed in leas per lb., and the draft required found by dividing the number of the rove into the number of the yarn. Thus the rove of which we have just been speaking, weighing 75 grammes per 50 yards, is in reality 300 yards per lb., or one lea, consequently the draft required to spin 10 from is $\frac{10}{1} = 10$. The number of any rove may be found by dividing 75·5 by the weight of 50 yards in grammes or by dividing the yards per ounce by 19, or by dividing 85·3 by the weight of 100 yards in drams.

Under the Scotch system of numbering, *i.e.* lbs. per spyndle, the order is reversed, and the draft obtained by dividing the lbs. per spyndle of rove by the lbs. per spyndle of yarn. The former is obtained by dividing 900 by the yards per ounce of rove, for there would be 900 yards per ounce in 1 lb. yarn or rove, or by multiplying the drams per 100 yards by 56. In practice it is necessary to give the yarn a longer draft than that theoretically calculated, since the twist, which is put into it after drafting, shortens or contracts by 1 to 12 per cent., the length delivered by the drawing rollers, and increases by a corresponding amount the weight per unit of length.

The draft, or the ratio between the surface speeds of the feed and drawing rollers of the dry spinning frame, is easily calculated, the wheels and diameter of the rollers being given. For instance—one of Walker's dry spinning frames has a feed roller wheel of 79 teeth working into a stud change pinion of 20 teeth compounded with a stud wheel of 34 teeth, which gears with the boss roller pinion of 30 teeth. The diameter of the top roller is $1\frac{3}{4}$ inches and that of the boss roller 4 inches, so that their relative surface speed or the draft of the frame is $\frac{79 \times 34 \times 4}{20 \times 30 \times 1\frac{3}{4}} = 10{\cdot}2$. If the draft change pinion be left out of this calculation, a constant number is obtained which, if divided by the draft required, gives the pinion which must be used. Thus in the frame which we have taken as an example, the draft constant is $\frac{79 \times 34 \times 4}{30 \times 30 \times 1\frac{3}{4}} = 204$, which, if divided by the required draft or 10·2, gives the draft pinion as 20.

The twist, in turns per inch, or the number of turns made by the spindles while one inch of drawn rove is being delivered by the boss roller, is found as follows :—

Suppose that upon the other end of the boss roller there is a wheel of 124 teeth gearing through an intermediate with the twist change pinion of 30 teeth which is placed upon a key on the pap of the crown wheel, which has 80 teeth. This latter wheel gears directly with the cylinder pinion, which we will suppose has 22 teeth. The tin cylinder is 9 inches in diameter and the wharve on the spindles $1\frac{1}{2}$ inches, hence the spindles make $\frac{124 \times 80 \times 9}{30 \times 22 \times 1\frac{1}{2}} = 90$ turns for one of the boss roller. The latter is 4 inches in diameter, or $4 \times 3{\cdot}1416 = 12{\cdot}6$ inches in circumference, hence the spindles make $\frac{90}{12{\cdot}6} = 7{\cdot}1$ turns for every inch delivered by the boss roller, or, in other words, the yarn is twisted at the rate of 7·1 turns per inch. By combining the two last calculations and leaving out the twist change pinion, a twist constant is obtained which, when divided by the turns per inch twist desired, gives, as a result, the necessary twist pinion. Thus in this case the twist constant is $\frac{124 \times 80 \times 9}{22 \times 1\frac{1}{2} \times 12{\cdot}6} = 214$, which, when divided by the turns per inch twist, or 7·1, gives the twist change pinion of 30 teeth as the result, thus $\frac{214}{7{\cdot}1} = 30$.

The damping roller for demi-sec spinning is clearly to be seen in fig. 58, lying in its trough of water situated between the drawing roller and the thread plate eye.

A long reach frame is required for ramie or rhea spinning, whether wet or dry, as the ultimate fibres are too long and strong to be drawn upon a short reach. A frame made by Messrs Greenwood & Batley of Leeds is the one most usually employed to spin this fibre. In this frame the distance between the drawing and retaining rollers is divided into three portions by two long rollers with light wooden pressings, which serve to control and render the draft uniform. The damping roller should always be used in the ramie dry spinning frame, as the hairiness of ramie yarn is one of its greatest faults.

Ring spinning is almost universally employed for ramie, since that fibre presents none of the difficulties in the shape of shove, etc., which have led to its almost complete abandonment in flax and tow spinning.

Twisting on the Ring Frame.—The theory of twisting on the ring frame is quite different from anything hitherto described. The winding of the thread upon the bobbin is done in the same manner as it is in the roving frame when the bobbin leads (see p. 139). In this case there is no flyer, its place being taken by the traveller, which is free to move round the ring. If every minute a length equal to the product of the speed of the bobbin or spindle and the circumference of the former were delivered by the rollers, the traveller would remain stationary upon the ring and the yarn would consequently receive no twist, but be merely wrapped upon the bobbin.

As in flyer spinning, the amount of twist may be regulated by altering the speed of the delivery roller, that of the spindles remaining constant. When every minute a quantity *less* than the surface speed of the bobbin is delivered to the spindle, it is taken up by the bobbin as before and the traveller pulled round upon the ring to compensate for what is wanting in length. Each revolution of the traveller round the ring puts one turn of twist into the thread, so that if the traveller makes twenty revolutions while one inch of yarn is being delivered, we say that the latter is receiving twenty turns per inch twist. From what we have said it will be seen that the twist which is being put into the yarn at any moment depends upon, or is affected by, the diameter of the bobbin at the point of winding on. This diameter of course varies from that of the empty bobbin or tube to that of the full pirn or cop. This is the objection which is most frequently urged against the use of the ring frame, yet if the variation in twist thus caused be carefully studied, it will be found in practice to be so small as to be unworthy of consideration. Suppose, for instance, that the roller delivers 14 yards = 504 inches per minute, and that the smaller diameter of the pirn is $\frac{1}{2}$ inch and the larger $1\frac{1}{2}$ inches, while the yarn is being wound upon the smaller diameter, the traveller will make $\frac{504}{\frac{1}{2} \times 3{\cdot}1416} = 321$ revolutions per minute *less* than does the spindle, and when the larger diameter is opposite the traveller, the latter will make $\frac{504}{1\frac{1}{2} \times 3{\cdot}1416} = 107$ revolutions *less* than the spindle. If the speed of the spindles be 4000 revolutions per minute, the maximum speed of the traveller will be $4000 - 107 = 3893$ revolutions per minute, putting in $\frac{3893}{504} = 7{\cdot}7$ turns per inch twist, while its minimum speed will be $4000 - 321 = 3679$ revolutions per minute, putting in $\frac{504}{3679} = 7{\cdot}3$ turns per inch twist, a variation of $7{\cdot}7 - 7{\cdot}3 = 0{\cdot}4$ turn per inch, which is equivalent to a little over 5 per cent. The variation is, of course, less marked in finer and harder twisted yarns.

Ring spun yarn is almost invariably built upon a pirn or tube in cop form, which lends itself very conveniently to winding off endwise and without strain. The pirn build referred to is effected by giving the builder plates, in which the rings are set, a slow and short upward traverse with a return about three times as quick, in order that every alternate row may be wound in a spiral of comparatively greater pitch, forming a binding thread to keep the yarn from ravelling off while winding or weaving directly from the cop.

Ring spindles may be run much quicker than flyer spindles, since they are not top-heavy and may be constructed on the Rabbeth principle. The best rings are rolled from solid steel without weld, great care being exercised in making them perfectly cylindrical. They are fixed in the ring, rail or builder in such a manner as to preserve the perfect circle. The friction of the traveller upon the ring is the chief difficulty experienced in ring spinning. When increased by the presence of dust and shove or water, it has led to the abandonment of the system, as in the case of flax and tow spinning, both dry and wet. The rings should be regularly oiled, and care must be taken that the diameter of the rings used does not bear too high a ratio to the smallest diameter of the tube, and that the weight of the travellers is suitable for the yarn being spun. When the yarn in passing from the traveller to the bobbin becomes the tangent of a comparatively small circle, and when the tension on the yarn at this point is split up into its component factors—*i.e.* a force pulling towards the centre of the ring and another pulling the traveller round the ring—it will be found that the latter force is comparatively small, hence it is that spinning on to the bare spindle is extremely difficult, and that when spinning on to a bobbin, the end generally breaks when it is being wound on to a small diameter. For this reason it is advisable to stop and start the frame when winding on to a large diameter.

In calculating the turns per inch twist upon the ring frame, it is usual to ignore the fact that the speed of the traveller is rather less than the speed of the spindle, so that this item may be found as in flyer spinning.

Ring frames are much more easily doffed than are flyer frames, since there are no flyers to be screwed off and on. The yarn does not drag the bobbin round, hence more yarn may be put upon the spindle than is possible in flyer spinning when the size of the bobbin is limited.

Experiments are now going on with a frame which, while possessing all the advantages of a ring frame, will, it is hoped, overcome all the difficulties hitherto encountered in employing that frame in the spinning of flax, hemp, tow and jute. The following are the main features of the frame to which we refer. The yarn may be wound in either cop or bobbin form. The step rail is lifted by the ordinary builder motion for ring or flyer frame winding. The spindle passes through a long collar, which protrudes on the upper side of the neck rail, and on a feather, through the wharve and the base of an open cup, which forms one piece with the wharve. The bobbin is fixed on the spindle and moves with it up and down, inside the above-mentioned cup. Upon the lip of the cup is a sort of flange, upon which turns a ring which has two eyes fixed in its upper edge. This ring is kept in place by an elastic ring, which is sprung into the interior of the cup, and which has upon it projections, half of which engage in a groove in the inside of the cup, and the other half with an inside flange in the revolving ring. The lower part of the wharve forms a sleeve which slips over the outside of the collar fixed in the neck rail, and forms the bearing upon which the cup is turned by the band passing round the wharve. The surfaces in contact work in an oil bath, for around each spindle is a cup forming part of the neck rail and containing oil.

Attached to the neck rail, back and front, are supports projecting upwards to the height of the revolving ring, their tops being horizontal with it. The drag bands are attached to the support at the back, and passing round a groove in the ring, hang over the front support and afford a means of retarding to the required degree the revolution of the ring with the cup. Were the ring to revolve at the same speed as the cup, spindle and bobbin, no winding would take place, but its motion is just sufficiently retarded to cause the bobbin to wind the yarn upon itself.

The strain upon the yarn is then very slight, and it is hoped that a fine yarn may be spun without difficulty upon a bobbin, holding from one to two thousand yards, and that the bobbins may be doffed as filled without stopping the frame, which should mean a high production.

CHAPTER XIII.

THE WET SPINNING OF FLAX, HEMP, AND RAMIE YARNS.

The Wet Spinning Frame.—Figs. 61 and 62 show the usual form of wet spinning frame used for spinning flax, hemp, and tow yarn. The bobbins, full of rove, are brought from the roving frame and placed upon wooden or wire skewers A in the creel B C D, fig. 61. Brass or porcelain footsteps are inserted in the planks C and D, which support the skewers and bobbins, in which steps the points of the skewers turn freely, while they are supported in a vertical position by the staples E, or in holes in the plank above. The creel must be made wider if the frame is to be used for spinning "double rove," for in that case double the number of bobbins must be put in the creel at one time in order that there may be two ends per spindle instead of one. The rove passes from the bobbin, as shown, over the brass guide rod F, which should direct it in such a manner that it passes between the back of the trough G and lid H (without rubbing against either) and round another rod, I, which is placed near the bottom of the trough T, containing water at a temperature of from 100° to 170° F. The rod I is placed low in the trough in order that the rove may be kept as long as possible under the action of the hot water and be sufficiently macerated. The trough is supplied with water and steam by feed-pipes connecting it with the main supply pipes which pass above the frames. The proper position of the steam pipe in the trough is shown at J. Since heated water rises, the pipe J must be placed low down and far enough from the line of the rove to prevent the latter from being scorched.

From the rod I the rove is drawn by the feed-rollers K, over the lip L of the trough and rove guide M. The object of the latter, which is given a slow and short reciprocating horizontal motion by an eccentric moved by a worm wheel and worm upon the end of the feed roller K, is to cause the rove to traverse backwards and forwards over the face of the roller so as to distribute the wear pretty equally over its surface, and in this way increase its life. Were the rove to remain in one place upon the roller a track would soon be created which would prevent the roller N drawing as it should. N is the boss or drawing roller, moving at from four to sixteen times the surface speed of the feed roller K, and effecting, by the aid of the pressing rollers O