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RESEARCH AND DEVELOPMENT ON VARIOUS METHODS OF
SPINNING SHORT STAPLE COTTON

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VIET NAM

Technical report: Small-scale processing of cotton*

Prepared for the Government of Viet Nam

by the United Nations Industrial Development Organization,

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C O N T E N T S

FIGURES

SMALL-SCALE MANUFACTURE OF TEXTILES

A review of the techniques by which low-grade cotton textiles may be economically manufactured within small rural comunities.

General

Textile manufacture embraces three main sub-processes - yarn manufacture, weaving or knitting and finishing. Technologically these processes have little in common and there is little, if any, advantage to be gained by combining them on one site.

Where modern high-technology equipment is used the three sub-processes are of roughly equal importance in terms of resources required, particularly man-power. Where small-scale manufacture is practised the situation is very different in that spinning is by far the most prodigal in the use of labour and most other resources. Using the simplest and least capital intensive methods of spinning and weaving roughly 20 spinners are needed to keep one weaver supplied with yarn when weaving typical apparel fabrics. Intermediate technologies can be used to reduce the ratio of spinners to weavers to about 4:1 but these necessarily require relatively high capital investment. High technolgy equipment, completely unsuited to small-scale working, achieves rough parity between spinners and weavers and, of course, greatly reduces the amount of labour needed to produce a given amount of cloth. In the high technology mills of today the amount of labour required to produce a given amount of cloth is from 1 to 10 thousand times less than that needed when using the simplest small-scale methods. Using intermediate technology can reduce the ratio to about 100 times but only at prohibitive capital cost.

Paradoxically the capital cost of high technology spinning plants is often lower than the cost intermediate technology machinery of equal productive capacity. However, this situation can be greatly ameliorated in situations where the textile workers are prepared to accept the cruder and simpler forms of intermediate technologies and where the equipment needed can be made locally by indigenous craftsmen.

Yarn Manufacture

SPINNING

The term 'spinning' is often applied to the whole process of yarn manufacture but in this paper it will be used as meaning only the final operation in yarn manufacture. The various pre-spinning processes to which cotton may be subjected include ginning, opening, cleaning, carding, combing, drawing and penultimate attenuation. The need for any or all of these processes is highly dependent on the system of spinning used and to a slightly less extent on the type of cotton.

1) The spindle-and-whorl

Without mechanical aids the making of all spun yarns is slow and tedious because of the amount of twist which is needed to bind the fibres together and, of all the materials which are commonly spun, cotton is the one requiring most twist. Cottons vary a little in regard to the amount of twist needed, those with short, coarse fibres requiring more than those with long fine fibres.

The earliest spinners probably made yarn in short lengths, twisting the yarn directly between fingers and thumb but it was not long before the technique of spinning by means of the simple spindle and whorl developed and used. The equipment needed is nothing more than a simple spindle of wood or bone to the lower end of which is attached a small clay, stone or hardwood disc to act as a flywheel to facilitate rapid rotation of the spindle. The process is necessarily a discontinuous one. During actual spinning the spindle is suspended from the yarn and kept rotating as the spinner draws out the fibres which are continuously being added to extend the yarn. When the length of yarn free between the tip of the spindle and the spinners upper hand has become as long as the spinner can conveniently handle, usually about one metre, he stops spinning and winds the length of yarn just spun on to the lower part of the spindle before returning to the basic task of drawing out more fibres and twisting them to form yarn.

Factors which made the spindle-and-whorl the universal spinning device until relatively recent times are:

i) It is cheap and simple to make. It is a crude but effective device capable of giving many years service which can be made quite quickly with only the simplest of tools.

ii) It is readily portable and with it yarn can be spun whilst standing, walking about tending sheep or riding on horseback.

2) The great (or 'Cottage') wheel

The great wheel uses virtually the same system of spinning as does the spindle-and-whorl. In its most common form it consists of a large, manually rotated wheel arranged to drive, by means of a cord, a single spindle carried in fixed bearings. The spinner works standing and, with the wheel and spindle rotating briskly. draws out fibres to extend the length of the spinning yarn, meanwhile moving away from the spindle until there is a length of about two metres of yarn free between the spindle tip and the fingers of his drawing hand. Twisting is continued until the yarn is judged to be sufficiently twisted and then, with the other hand, he stops the wheel, turns it backwards a little to unwind the few coils of yarn on the spindle blade, and proceeds to wind the yarn just spun on to the lower part of the spindle before beginning the cycle again.

Although much more productive, the great wheel has not by any means entirely displaced the simple spindle-and-whorl. Reasons for this situation are:

i) It is, relatively, a very expensive piece of equipment to make.

ii) It is not readily portable

iii) It cannot be used when walking or tending livestock.

3) The Brunswick (or Saxony) wheel

The Brunswick wheel is a widely used embodiment of a principle of spinning by means of which twisting and winding up the yarn can proceed together. The essence of this system is the same as that used in roving frames, spindle-and-flyer frames and ring frames. The bobbin of spun yarn and a yarn guiding device are both rotated continuously in the same direction about a common axis with a speed differential such that yarn is wound on to the bobbin at the same time as the yarn forming between the spinners hand and the yarn guide is being twisted. The arrangement by which this is done is shown in Fig 3.

Being a more complex device it is even more expensive to make than is the great wheel and, like the latter, it is not readily portable. Because it is a continuous process it is simpler to operate and time does not have to be spent stopping the spindle in order to wind up the successive lengths of yarn spun. Against this advantage must be set the fact that power required to drive the spindle of a Brunswick wheel at a given speed is very much higher than that required to drive the spindle of a discontinuous spinner. This is not a matter of details of design and construction, it is a fundamental weakness of all such systems of combined winding and twisting systems.

Because of this the Brunswick wheel is widely used for the spinning of flax, hemp, jute and woollen yarns. It is not suitable for the spinning of fine yarns from long-staple cottons but is worthy of consideration for the spinning of cotton yarns coarser than about 12s English cotton count.

4) The jenny

The spinning jenny was the first device which successfully enabled one spinner to spin many ends (threads of yarn) simultaneously. Essentially it is little more than a multiple form of 2) above, the great wheel. The fundamental principle is that of taking a number of short lengths of roving (lightly twisted lengths of fibres many times thicker than the yarn to be spun) and drawing them out steadily whilst continuing to introduce twist into the forming yarns by rotation of a number of spindles driven by a common wheel. Several, or even many, spindles may be driven by cords from a single , manually rotated wheel and to enable the spinner to draw out a plurality of rovings a wooden clasp (known as a clove) is provided. The clove is mounted on guides such that as, with the spindles turning, it is drawn back to attenuate the roving it will remain parallel to the row of spindles. When drawing out is completed the spinner continues to turn the wheel, and hence the spindles, until the yarns are sufficiently twisted. He then turns the wheel backwards a little to unwind the few coils of yarn which lie on the bare spindle blades. He next pushes the clove towards its initial position close to the spindles whilst at the same time turning the wheel slowly in the forward direction so as to wind the yarn just spun on to the lower parts of the spindles. He now releases the grip of the clove on the rovings and draws back the clove to free a short length of roving to each spindle. The clove is then tightened to grip the rovings and the whole cycle is then repeated. The operating cycle is illustrated in Fig 4 and the arrangement of the working elements is shown in Fig 5. Not all jennies operate horizontally, vertical arrangements are used where floor space is limited but, whether horizontal or verticle the jenny is a device easily built by village craftsmen.

Together with simple equipment for the preparation of rovings the jenny, in its crudest form, will enable a spinner to increase his output of yarn ten-fold without incurring any greater capital investment than that which would be needed to provide the ten great wheels which would be required to produce the same amount of yarn. It is perfectly practicable to build jennies with greater numbers of spindles but for purely manual operation the maximum number of spindles which one spinner can manage is about twenty. This number can usefully be greatly increased if power can be used to drive the spindles during the drawing and twisting part of the operating cycle. Where power is available it is a simple matter to arrange that it is automatically harnessed to drive the spindles at the appropriate times leaving the spinner to operate the jenny during the remainder of the cycle manually. With this sort of arrangement a male spinner assisted by a young person can operate a jenny of up to 200 spindles.

5) The water frame

The waterframe was so called because it was designed to be driven continuously by means of a water wheel. It combines the continuous spinning device of spindle-and-flyer as used in the Brunswick wheel with the concept of metering roving, similar to the roving used in jenny spinning, to each of a number of spindle-and-flyer units by means of pairs of rollers. A water frame is shown schematically in Fig 6. In this particular form the roving passes successively through four pairs of drafting rollers to give primary attenuation prior to the roving entering the secondary attenuation zone. The relative speeds of spindles, flyers and drafting rollers are so arranged that the fibres of the forming yarns are further drawn out in roughly the same way as is done by the hand of the spinner in greatwheel spinning and in jenny spinning. The object of secondary attenuation is to draw out preferentially any unduly thick places and thereby improve the regularity of the yarn. The degree to which this can be done is significantly lower than is achieved with the discontinuous systems and as a compensation for this weakness it is necessary to provide roving of greater uniformity than is needed for jenny spinning.

Like the Brunswick wheel in relation to the great wheel, the water frame is at a considerable disadvantage in relation to the jenny in that much more effort is required to drive it. For this reason it is seldom used in manually driven form with more than four spindles and is only viable for the spinning of coarse low-twist yarns. It has, however, the very great advantage that. when power driven, it will spin continuously and consistently for long periods without any direct human involvement. It is itself the spinner; the major attention which the machine requires is occasional renewal of the supply of rovings and the more frequent removal of completed bobbins of yarn. Beyond this , all that is needed is routine cleaning and lubrication.

6) The hand mule

The hand mule, or 'mule jenny', is essentially a jenny which uses drafting rollers to control, and at the same time attenuate, the roving supplied to the drawing and twisting zone. This feature enables the machine to produce finer and more uniform yarn than is possible with any other simple machine. It is similar in method of operation to the basic jenny but simpler in that the arrangement by which the drafting rollers are driven ensures precise feeding of rovings to each draw - a feature which improves yarn uniformity and rēduces dependence on the skill and judgement of the spinner.

Like the simple jenny, the mule jenny can have a great many spindles but the maximum number recommended for purely manual operation is about twenty. Again as with the jenny, this number may be increased to about 200 by applying power to drive the spindles during the drawing and twisting part of the cycle. The quality of roving needed for satisfactory operation is the same as that needed for ordinary jenny spinning. The greater uniformity of roving which the water frame demands is not necessary

7) Frame spinning

Three methods of frame spinning are all refinements of the system of continuous spinning embodied in the Brunswick and in the water frame. That is , simultaneous winding-on and twisting of the yarn is achieved by arranging that the yarn bobbin rotate co-axially within a rotating yarn guiding device. The refinements are all concerned with simplification of the construction and increasing the speed of rotation. The throstle uses a very lightly constructed flyer similar in other ways to the flyers used on modern speed frames. In the cap spinner (sometimes referred to as the Danforth throstle) the yarn is guided by the lower edge of a co-axial cap as shown in Fig 7. The ring frame uses a very small wire 'traveller', constrained to move round a circular track (the 'ring') co-axial with the spindle to act as yarn guide. This very widely used system is shown in Fig 8. All three devices are used in conjunction with drafting rollers which meter fully attenuated roving to them at the required constant speed. As there is little, if any, secondary attenuation during twisting, a high standard of roving uniformity is necessary.

The throstle is the most expensive device to make, it cannot be operated at such high speeds and it requires more driving power than do its rivals. It has, however, two virtues - it can be used to spin very soft full yarns and it is not unduly sensitive to the speed at which it is driven.

The cap frame is the cheapest to build and has a low driving power requirement. It is also capable of spinning fairly soft full yarns but, especially when spinning such yarns, it is necessary for it to be driven at a reasonably constant speed. Big variations in speed greatly affect the tension under which the yarn is being twisted and this results in marked changes in the fulness and the general character of the yarn.

The ring frame is the most difficult to manufacture because of the precision with which a number of small components, such as the rings themselves, must be made and heat treated. Total manufacture by local village craftsmen cannot be recommended but if the few critical components can be provided by specialist engineers it is quite possible to build the machines locally and in small batches. In general the higher cost of ring frames is more than offset by the higher speeds at which they will operate except where very full soft yarns are to be spun.

Like the water frame, all three of these devices when coupled to a source of rotary power will spin continuously for long periods without attention. Labour is required only for the replenishment of the roving supply, removal of completed bobbins of yarn and general supervision. At the lowest level of working human rotary power may be used. This is common in India, a country with a large and long established industry based on cottage spinning. The coming of large-scale, power-driven mills had a disastrous effect on rural economy. To counter this a great deal effort has been directed to the development of small-scale spinning machines suitable for cottage use in rural areas. Much of this effort has been concerned with the design of small, manually driven ring frames and throstles. The smallest machine, known as the Ambar charka, is a very small ring frame very lightly constructed, mostly from wood. It is readily portable, has four very small spindles which can be driven, by hand, at 8000 revolutions per minute without undue fatigue. This is an enormous advance on single spindle spinning and, forty years ago at the time of its inception it was truly viable Since then continuing industrialisation of the country has progressively reduced the viability of the Ambra charka and led to a demand for manually driven charkas capable of higher and higher productivity. The result was the New Model charka which has six not-so-small spindles. It is more substantially built, is heavier to drive and it is not so readily portable. It does however enable cottage spinning to continue as a rural industry in India.

Pressure to further increase charka productivity grew, and the way to do this seemed to be to increase the number of spindles of the New Model charka. It was, however, appreciated that a law of diminishing returns must be applied to any increase in the number of spindles. The four-spindle Ambar charka could be driven at 8000 revolutions per minute giving a total twisting rate of 32 thousand turns of twist per minute. The same amount of power applied to a six-spindle NM charka gives a spindle speed of only 6500 revolutions per minute and, hence, a total twisting rate of only 39 thousand turns of twist per minute. When full account is taken of the higher cost per machine as the number of spindles is increased it becomes clear that to increase the number of spindles of a hand-driven, small-scale ring frame beyond six would not be worthwhile. Accordingly development has more recently been directed to the design of pedal or treadle driven ring frames with some success.

For either pedal or treadle driven operation much more substantial methods of construction are needed but, except for a few small specialist components, such charkas can be made in simple rural workshops. Many are now in use, mostly with eight or twelve spindles and with the more successful of these, a healthy adult can maintain a total twisting rate of about 80 thousand turns of twist per minute. This is, of course, an enormous advance on single spindle spinning but it is a strenuous task which, in terms of job satisfaction is lttle better than driving a treadmill.

Where power is available these relatively cheaply built ring frmes frames are sometimes ganged together and driven by a small electric motor. Commonly a nominal ½HP motor drives four frames, each of 12 spindles, at 10,000 revolutions per minute so giving a total twisting rate of 480 thousand turns of twist per minute.

Quite separately from this charka development considerable progress has been made in the design of simple, low cost spinning machines to be power driven in small rural mills. These mills are very much cheaper to build than are high technology mills and have the great advantage that satisfactory operation and maintenance is within the capability of relatively primitive rural labour. The output per worker is very much lower than in high-tech mills and the quality of the yarn produced is markedly lower. However, such mills are certainly viable in rural areas and the lower quality of the yarn is no real disadvantage in the end uses to which it is likely to be put.

There is experience in India of the operation of small-scale (400 to 500 ringspindle) mills using locally made machinery. They have been found capable of producing coarse to medium (10s to 20s) count yarns , of adequate quality for small-scale weaving, at costs alittle lower than those of new or existing full-scale (25. to 35,000 spindle) mills. As these costings include fixed and working capital costs as all direct operating cost, such mills are regarded as a sound economic proposition and have attracted private capital for their establishment

3) Open-end spinning

Open-end spinning is a development of the last 25 years, it is a method of spinning which permits direct winding of the spun yarn onto very large packages. The most common form of open-end spinner is shown schematically in Fig 9. Card sliver passes into the spinning unit through a miniature dish-feed and is opened by a licker-in type cylinder, about 2½" in diameter, running at 6,000 to 8,000 revolutions per minute. The opened fibres are carried to the inner surface of the spinning pot in an airstream which is maintained partly by the fan action of the licker-in and partly by the centrifugal pumping action of the pot itself. The yarn is withdrawn through a fixed baffle plate which serves to prevent ingoing fibres from being prematurely attached to the yarn surface.

The ability to deliver yarn directly on to very large packages is a great advantage for large-scale working and much high-technology has been lavished on the development of high productivity open-end spinning systems, Large package delivery is of little advantage in small-scale spinning but open-end spinning has three important attributes which will be of value in small-scale working. These are, relative to ring spinning:

i) Speed for speed it requires much less driving power

ii) The working elements are less complex and fewer in number

iii) The expensive pre-spinning processes of drawing and penultimate attenuation are not required.

All three of these features are very desirable in small-scale working and a great deal of effort is currently being applied to the development of low-technology, low-cost open-end spinners. Several single spindle, treadle driven machines have been built as well as four-spindle power driven models. These are designed to be made by rural craftsmen from commonly available materials in rural workshops. Operating experience to date has been encouraging and there is little doubt that small-scale open-end spinning, either treadle or motor driven, will be economically viable for coarse yarns. There is also every expectation that it will later be developed for medium to fine yarns.

Pre-spinning processes

The pre-spinning processes are:

i) Ginning

ii) Opening and cleaning

iii) Carding and combing

iv) Drawing

v) Penultimate attenuation

Only ginning is an absolutely necessary preliminary when using any one of the three single-spindle devices described above. It will however generally be found that a modicum of opening, cleaning and carding is well rewarded in terms of increased productivity and superior yarn quality. With all multiple spindle spinning devices all the above processes need to be employed. to a greater or lesser extent depending on the numbers of spindles per device, the nature of the cotton being used and the quality of yarn desired. In modern large scale ring-spinning mills the cost of post-ginning/pre/spinning processing costs roughly as much as the spinning processing itself in terms of capital investment, power consumption and operative wage costs.

GINNING

At the time of harvesting the seeds bolls the cotton fibres are very securely attached by their 'tails' to the seeds themselves. The basic objective in ginning is to separate the cotton fibres from the seeds. This can be done quite simply and satisfactorily by human fingers but, unfortunately, this is a very slow process but not, however, impossibly slow in relation to single-spindle spinning. It is, therefore, completely practicable to gin by hand where over-riding circumstances preclude the use of a ginning machine.

1) Simple roller gin (or churka)

The Indian churka is a very simple machine. It consists of only two small rollers mounted horizontally at such a separation that seeds cannot pass between them. The rollers are rotated by means of a cranked handle and seed cotton is fed to them. The lint fibres are caught up by the rollers and drawn forward so that they are torn from the seeds, which cannot pass between the rollers. Being simple and crude, this type of gin can easily be made at low cost by village craftsmen and it is typically capable of a throughput of about five pounds of lint per day.

2) Other roller gins

The Macarthy gin is often referred to as a roller gin and it is, in fact, a roller gin although it does not work in the crude way in which the simple roller gin does. A common form of Macarthy gin also has two horizontal rollers but these are covered with very rough-grained leather and are much larger (8" to 10") in diameter. Seed cotton is fed through a hopper immediately above the rollers, The rough leather drags the seed cotton past closely set doctor blades which effectively remove the seeds and allow the lint to go forward.

In another form of Macarthy gin seed cotton is pressed on to a single leather covered roller from a smooth horizontal feed plate by means of a reciprocating 'pusher'. The surface of the roller is moving upwards at this point and, immediately above the pusher. is a closely set doctor blade oscillating in a manner which detaches the seeds from the fibres. The feed plate also oscillates in a way which allows the seeds to fall clear whilst the lint is carried over the top by the roller into a receiver

Macarthy gins are made in a wide range of sizes. The smallest may be hand driven and capable of a through-put rate 20 to 60 pounds of lint fibre per hour. Larger gins, which must be power driven, have through-put rates up to 200 pounds per hour. The smaller sizes can be made in rural workshops but the making of gins of the larger sizes is better left to specialist manufacturers.

3) Saw gins

The saw gin works on a wholly different principle which at first sight appears to be so brutal as to inflict serious damage on the delicate cotton fibres. In fact it is no more prone to this than are the apparently much gentler roller gins. The principal feature of a saw gin is a heavy, horizontal shaft carrying from 50 to 200 ganged circular saws, typically about 12" in diameter and spaced about ¾" apart along the shaft. The saws project a little way through narrow slits in a vertical plate forming one side of a hopper within which the saws rotate. The feed cotton, in a fairly compact state, is piled above the rotating saws, the teeth of which are continuously engaging tufts of fibre with attached seeds and drawing them through the narrow slits. As the seeds will not pass through the slits they are detached from the fibres and fall down between the saws. The detached fibres are then stripped from the saw teeth by means of either a rotating brush or an air blast.

Very large modern saw gins are huge complex machines each capable of a through-put of about 5000 pounds of lint fibre per hour, delivering this automatically as wrapped, highly compressed bales weighing about 450 pounds each. Clearly such large machines are inappropriate for small-scale rural working but quite small saw gins also are made and these are well able to deal with low quality, short staple cottons.

OPENING AND CLEANING

In ordinary full scale mill practice baled cotton passes through a succession of several large machines with the two-fold object of breaking the mass down into very small tufts and extracting such trash as stalk, leaf, seed coat and dust. The broad principle of the machines is to strike and beat the cotton with rotating spiked or bladed beaters and allow the trash to fall out, by means of various stratagems, as the material passes from one beater to the next. These opening and cleaning lines are typically proportioned to have an output of 500 to 1000 pounds of clean cotton per hour.

A modern coarse-to-medium count large-scale mill equipped with 25,000 ring spindles would be adequately served by two of these machines. Clearly this is much too large a machine to have any place in small-scale spinning. Just one of them would be able to serve

10 small-scale mills of 150 locally made ring spindles
1000 treadle driven, 6 spindle charka spinners
4000 single spindle great-wheel spinners.

It is just practicable to do all the opening and cleaning needed without recourse to machinery. For single-spindle spinners there is no problem at all as each spinner can, with advantage, be responsible for all pre-spinning treatment of the ginned cotton. For all multiple spindle spinners and small-scale mills some centralisation of pre-spinning processing is desirable. Even here the opening can be done directly by hand and the cleaning then done by scutching the opened cotton with light willow wands or the classical strung bow.

As a more pleasant and less dusty alternative, opening can be done by one or two passages through a locally made, single-beater opening machine. The opened cotton may then be cleaned mechanically using a simple willowing machine, which may also be locally made at modest cost.

In mill practice it was long the custom for the opening-and-cleaning line to deliver its product in the form of a 'lap', a compact roll of cotton weighing about 40 pounds, 40 yards long and 40" wide. This form of delivery is now giving way to direct shute feeding to the cards. These forms of delivery are very convenient but experience has shown that neither is suitable for small-scale working. It is strongly recommended that the output from the opening and cleaning processes should be in the form of loose open cotton, preferably in bins.

CARDING

The object of carding is the removal of entanglements which exist between fibres so as to facilitate the smooth drawing out of fibres during later processes. The extent to which this is necessary depends on the type of cotton, the fineness of the yarn to be spun and the nature of subsequent processes. For rough coarse yarns it is just possible with care and great skill to spin on a single spindle but this is tedious business and even a little carding before starting to spin is well worthwhile.

1) Hand cards

For single-spindle spinners the equipment needed is just two hand cards - two flat pieces of wood, each with a wire-brush surface attached to one side. A small handful of cotton is laid on one card and the fibres are progressively straightened by a brushing action applied by the other card. The layer of cotton may be worked from one card to the other until all major entanglements have been removed, and it is judged that the fibres are sufficiently aligned. The thin sheet of fibres is then carefully removed from the lower card and then lightly rolled to form a cylindrical bundle in which individual fibres lie substantially along the axis of the roll or bundle. When enough of these carded bundles have been prepared they are joined end-to-end to form a soft rope which, because of the axial alignment of the fibres and the freedom from serious entanglements can be drawn out easily and smoothly in spinning.

It is quite practicable to make slivers suitable for multi-spindle charka spinners from material prepared using only hand cards. Although slow in relation to mechanised carding it is not slow in relation charka spinning productivity. A spinner with a six-spindle treadle driven charka could card enough material for a days spinning in less than one hour.

2) Simple rotary cards

The classical mill cards have a typical productive capacity in the range 5 - 20 pounds per hour depending on the type of cotton being used. This is not inconveniently large for small-scale use but these cards are quite unsuitable for rural use. This is largely because of the high degree of precision involved in their construction and maintenance but also because of the fact that they are very easily (and expensively) damaged by careless or unskilled operation. For these reasons simple rotary cards of various types are used.

The simplest type is manually rotated. Like a mill card it has a feed-plate and roller set close to a small licker-in cylinder which throws small tufts combed from the feed roller nip on to the surface of the main cylinder. The main carding action takes place between the rotating cylinder and a small number of stationary, but readily removable flats mounted above the cylinder. A web of carded fibres is contiuously being stripped from the cylinder by a doffer cylinder which, in its turn is stripped by an oscillating comb as used in mill cards. This is the commonest way of working but many small rotary cards do not have means for automatic doffing of the web. These need to be operated batch-wise. A roughly weighed quantity is fed to the licker-in, this is automatically transferred to the the cylinder which is then kept turning until the operator judges that sufficient carding has been accomplished. He then stops the cylinder and carefully removes the carded material in a sheet as wide as the cylinder and as long as the circumference of the cylinder. Usually the sheet is then cut into strips longitudinally ready for drafting on a single zone, manually driven drafting device. Where automatic continuous stripping of a web from the cylinder is practised the web is usually drawn through a condenser trumpet to form a sliver which is then coiled into a small sliver can. It is necessary to remove the flats from time to time in order to strip them of short fibre and such impurities as fragments of seed coat.

The great merit of these simple rotary cards is that they are cheap to build, very robust and tolerant of rough usage. Naturally the quality of carding achieved is far short of modern mill standards but it is adequate for a great many rural end uses. Typically those cards intended to be manually driven have a working width of about 8" but where power is available working widths of about 24" are more usual. The frames are usually made from wood as also are the cylinders and the flats. The clothing of cylinders and flats may consist of sharpened steel pins driven through hardwood lags or, depending on local availability. classical fillet clothing nailed to wooden lags. The flats are not screwed or bolted to the machine but rest with their ends in suitably placed slots from which they are easily removed.

Cards of this general description but usually more heavily constructed with metal cylinders and main frames, have been found satisfactory for use in service centres set up to provide groups of charka spinners with roving and also in small-scale mills. In these situation it is tempting to suppose that secondhand mill cards would be a better buy. Experience has shown that this is not so because it is difficult to attract skilled card maintenance men to work in rural situations and it is also difficult to get rural worker to accept the strict operational practices which are necessary to avoid expensive damage to card clothing.

3) Roller-and-clearer cards

Roller-and-clearer carding, which has been widely used for many different fibres is no longer the preferred mill method of carding cotton. The revolving-flat card has largely displaced the roller-and-clearer card on the grounds of the much higher carding quality which it gives. The quality improvement is very important to the spinners of fine yarns from long-staple cottons. In the later days of the roller-and-clearer card it became common to card twice or to use tandem cards but, for most cottons, this became unnecessary with the coming of the revolving flat card. A penalty had to be paid for the improved performance - the expensive working elements are very much more easily damaged by trash in the cotton or by slipshod performance of the card tenders duties. For this reason the roller-and-clearer card is still prefered for mill processing of waste and low grade cottons as well as for wools. It follows that it is logical that roller-and-clearer carding is the more appropriate for small-scale carding of cotton in rural situations.

In general structure the roller-and-clearer card is very similar to the simple rotary card, 2) above, and the revolving flat card, 4) below. It has feed-plate and roller, licker-in, main cylinder and doffer - the last three of these having finely, but sharply, spiked working surfaces. The important difference is that, instead of the carding taking place between the main cylinder and a number of flats, several pairs of carding rollers are mounted close to, and above, the main cylinder. The rollers of each pair are known respectively as the worker and the stripper. The worker is typically 5" to 8" in diameter and is driven at a low speed, the stripper, 3" to 4" in diameter, is driven at a high speed such that its working surface is moving in the same direction as, and at about half the speed of, the main cylinder surface. The slow moving workers act almost as flats to straighten out fibres passing by on the rapidly moving surface of the main cylinder and at the same time they pick up layers of fibre for themselves. These fibres are further straightened by the action of the adjacent stripper which, moving much more quickly, pulls fibres from the worker and returns them to the main cylinder.

The stripping of the carded web is done by either of two methods. One of these is to arrange that the web is a very light one and to strip it from the doffer by means of an oscillating comb before condensing it into a single sliver by drawing it through a trumpet. The alternative method is to form a slightly heavier web and remove it from the doffer as a number of continuous bands which can then be made directly into slubbings by means of rubbing aprons or by twisting them lightly into rotating cans. The first of these methods, followed by drawing operations, leads to stronger and more uniform yarns, but at the expense of needing the use of drawframes and speedframes before spinning. The second method offers the great advantage that spinning can be done directly from the slubbings produced by the card. Although the resulting yarn is inferior in strength and uniformity it has a pleasing fulness which is to be preferred in a number of end uses. For rural situations lacking higher technical skills and with access only to low grade cottons the roller-and-clearer card producing slubbings directly is most strongly recommended.

For any system of continuous carding it is important that the rate of feeding should be kept reasonably constant. When delivery is to be in the form of slivers or slubbings it is essential that the feeding rate should be kept absolutely constant or great difficulty will be experienced in maintaining yarn count uniformity. In mill scale carding this problem is dealt with by feeding opened cotton in the form of a tightly wound lap weighing about one pound per running yard. This is an excellent system but it is very dependent on the availability of an automatically controlled lap making machine. Unfortunately, the design of these machines is such that they will maintain the weight per yard of the lap very precisely under continuous running conditions. They will not work properly when run only spasmodically and they are very expensive to buy and service. In short, they are quite impracticable for small-scale working. For this reason it is recommended above, under 'opening and cleaning', that opened and cleaned cotton should be delivered in loose form into bins.

As an aid to providing a sufficiently uniform feed it is recommended that each card be fitted with an open, continuously running, feed lattice boldly marked with transverse lines at uniform intervala of 20" or so. The operator will be charged with taking appropriate weighed quantities of cotton from the bin and spreading each weighing as uniformly as possible between successive transverse markings on the feed latice. To facilitate the entry of the loose material into the nip of the feed roller a light wooden consolidating roller widely fluted and about 6" diameter should be provided immediately before the feed roller.

4) Revolving-flat cards

The revolving-flat card is basically nothing more than a mechanised form of the simple rotary card, of 2) above, in which the actual carding takes place between the surfaces of the main cylinder and a number of flats set close to the cylinder surface. This extremely effective way of carding cotton was only superceded by the less effective system of roller-and-clearer carding because of the mechanical difficulties which were encountered in attempts made to automate the stripping of short fibre and trash from the flats. There was no shortage of ideas as to how this might be done but, even so, it was many years before a successful automatic 'flat' (as distinct from 'roller') card appeared. This breakthrough came only when the machine makers realised, and the spinners were ready to accept, that much greater precision in manufacture, location and maintenance of all critical working elements if progress were to be made. The breakthrough was the now-classical revolving-flat card which became almost the universal cotton carding machine for full scale mill use.

Because of its better carding performance the revolving-flat card was quickly taken up by the spinners of high quality, fine and superfine, yarns and more slowly adopted by spinners of the less demanding yarns. The relative delicacy of the new machine and its need of great care in the setting of very small clearances between the various carding surfaces led to a marked upgrading of mill personnel concerned with carding and an acceptance of the need for higher standards of opening and cleaning. Spinners of coarser yarns from low grade cottons continue to use roller-and-clearer cards.

Clearly the revolving-flat card is not a machine to be introduced lightly into rural areas where the workers do not already have a background and traditions of mill-scale cotton processing. It would certainly be necessary to bring in a nucleus of mill-trained staff and to incur further expense in the pre-carding processes. Successful use of revolving-flat cards would undoubtedly improve yarn appearance and reduce the rate of yarn breakage in both spinning and weaving, but would this be worthwhile for our present purpose? These features of better carding enabled mills to increase the number of spindles which one spinner could tend to about 1,000 and the number of looms which one weaver could tend to about 80. This would be gross 'over-kill' in relation to low-capital-cost, small-scale working in rural areas.

5) High production cards

Until relatively recently a typical spinning mill with 25 thousand ring spindles required only two opening lines, each feeding 50 cards. The thought of using micro-computers to control the whole of the pre-spinning processing opened-up the further possibility of completely un-manned spinning. The major obstacle to this was the necessity of having to have simultaneous flow through about 50 channels at the carding stage. Great pressure was applied to the solution of this problem and the modern high production card is now able to handle the whole production of one opening line. These huge and incredibly expensive machines are now single items in a machine line which starts with an assembly of bales ready for breaking and ends with sliver ready to go directly to the creel of an open-end spinning frame. Although the concept and principles of open-end spinning could well find application in small-scale there seems to be nothing in high production carding which has relevance.

DRAWING

Coarse to medium count, full and lofty yarns can be spun directly from card sliver, slubbing or roving but where compact, high-strength yarns are wanted the fibres must be drawn after carding. It is a simple, low-power and low-cost operation which can be carried out by means of either simple drafting rollers or a drafting arrangement within which a small amount of twist can be introduced.

1) Drawing without twist

The simplest mechanical device is a basic, two-line drafting unit consisting of only two pairs of rollers with a fixed draft ratio of about 4 to 1. For single-spindle spinners even this is more than is strictly necessary. A skilled single spindle spinner contrives to provide the required amount of drawing continuously as the fibres pass through his fingers before entering the spinning zone. For individuals or small groups of multi-spindle charka spinners the simple hand-driven, two line drawframe is ideal and one could easily meet the needs of from 5 to 10 such spinners.

The method of use is simple and undemanding. Four equal lengths of carded sliver (made after carding on a simple rotary card or by means of a pair of hand cards) are placed side-by-side and passed through the 2-line drawframe. The delivery is consolidated into a single sliver of substanially the same weight per unit length as the original card sliver. The once-drawn sliver is then divided into four equal lengths which are placed side-by-side and passed again through the drawframe. This process is repeated until it is judged that the fibres are sufficiently well aligned for attenuation to proceed smoothly. Four passages of drawing are usually enough. Where a suitable weighing device is available and the lengths of sliver used is standardised it is easy to maintain consistency of yarn count.

For larger installations using a card, or cards, fed at a uniform rate and delivering sliver continuously it is better to use drawframes arranged for continuous operation and with automatic sliver coiling facilities. The classical (pre-1950) mill type drawframe is ideal except for the fact that they were commonly made with six or eight deliveries per frame. For small-scale working the number of deliveries should not exceed two. Secondhand mill machines can easily be converted to two delivery working, or local engineering companies can easily construct machines which would be suitable. The general specification would be for three or four pairs of drafting rollers to give two or three drafting zones, arranged to give a delivery speed of about 100' per minute. Each delivery should have guides to keep separate six ingoing slivers and the overall draft ratio should be six. A pair of calender rollers should be provided to consolidate the delivered material into sliver form by drawing through a trumpet. The type of coiler used on mill cards and drawframes could be used but this not really necessary for small scale working. Loose delivery into small bins is simpler.

Generally two or three passages of drawing will be needed. In mill practice it was usual to achieve this by putting three drawframes one behind another so that six of the cans delivered by the first frame would be the feed to the second frame, and similarly from the second to the third frame. For small-scale working only one drawframe may be needed, the same material being passed three times through the one frame.

2) Drawing against twist.

For roller drafting to be successful it is necessary for the distance between successive roller nips to be just a little greater than the length of the fibres. If it is too great there will be a tendency for fibre movement to be initiated at the weakest point and for movement there to continue until the now further weakened place has passed through the outgoing nip. This difficulty can be overcome by drafting against twist. The principle involved in this is that when a lightly twisted sliver is being drawn the twist tends to run into the thinner places thus strengthening them in such a way that fibre movement is more likely to occur in the thicker places. By continuously introducing twist progressively as drawing proceeds the uniformity of a sliver can actually be enhanced. Skill is needed in doing this as excessive twisting will lock up the fibres and merely result in breakage.

This principle had long been exploited by single-spindle spinners and jenny spinners and can also be used to align the fibres in slivers. A larger and more substantially made version of the great wheel is used to do this. At the start of each draw the operator grips the sliver about one foot away from the spindle tip with one hand and sets the wheel turning with his other hand. He then proceeds to draw out the sliver to a length of about five feet, meanwhile taking great care to ensure that the amount of twist at any time is such that uniform drawing will continue to occur. He then winds the drawn sliver, now more properly slubbing, on to the spindle in a loose cop fashion which will facilitate overend unwinding from the spindle. Substantially the same process is carried out on a multi-spindle machine known as a slubbing billy which is basically a larger version of the spinning jenny. When these processes are used roller type drawframes are not needed. One slubbing billy is adequate for yarn counts up to about 20s but for finer counts a second process on a roving billy will be needed

PENULTIMATE ATTENUATION

Penultimate attenuation is the term applied to the processes by means of which drawn sliver is attenuated to such a degree as is necessary before actual spinning can begin. The degree of attenuation needed is highly dependent on the count of yarn to be spun and, to some extent, on the type of spinning system used.

Single-spindle spinners are able to make fairly good yarn from cotton which has merely been carded although, generally, the yarn will be better and the work of spinning more easily performed if the carded cotton is presented as lightly drawn sliver.

1) By slubbing billy

Where jennies or hand mules are used for spinning it is usual to use a slubbing billy to achieve the needed degree of attenuation. This is certainly the most economic way of working in relation to capital cost and also in relation to the use of technologically competent personnel. It does, however, involve the use of larger numbers of workers possessing natural manipulative skills.

So long as the carded cotton has been well drawn the range of final draft ratios which a jenny spinner can work with is from $2\frac{1}{2}$ - 10 to 1. In other words the weight per unit length of the slubbing or roving from which he can spin should be from $2\frac{1}{2}$ to 10 times that of the yarn to be spun. For most efficient working the roving should be from 6 to 8 times heavier than the yarn to be spun. As the hand mule is provided with a simple roller drafting system the ingoing roving may be up to 25 times heavier than the yarn and, for good work, should not be less than 5 times heavier.

Although drawing and pre-spinning attenuation against twist is commonly associated with jenny or mule spinning it is equally suitable for the preparation of slubbing or roving for frame spinners. A 12-spindle jenny spinner of medium count yarns (12s - 20s) can easily do all his own pre-spinning preparation using only a pair of hand cards followed by attenuation against twist using a single-spindle billy. These items of equipment are so simple and of so rugged a construction that they can be made by a village craftsman in two or three days. In use the equipment is so robust that virtually no maintenance is needed.

For a service centre charged with supplying slubbings or rovings to a group of spinners (jenny, mule or frame) more appropriate equipment would be a simple rotary card followed by a slubbing billy of about 12 spindles. Again, the equipment can be locally made and in use would be almost maintenance-free. It certainly would not require the presence of technician or technologist once the personnel of the centre had received initial training.

2) By speed frames

Pre-spinning attenuation by means of billies has the disadvantage that it is a discontinuous process which requires a modest degree of skill and manual dexterity on the part of the operator. The alternative, the speed frame has the merits of running continuously and of requiring very little skill and virtually no manual dexterity on the part of the operative. It is however highly dependent on the services of moderately skilled technicians and of experienced spinning technologists.

Modern high-draft speed frames are completely unsuitable for rural operation. The most advanced type of speed frame which can even be considered for small-scale working is the classical pre-1950 mill type and even this is too complex and too highly productive a machine for most small-scale situations. For successful operation it is necessary to have both competent technicians and in-plant discipline which will ensure a high standard of operational care and working cleanliness.

The Achilles heel of all speed frames is the mechanism by which the soft, low-strength slubbing or roving leaving the drafting rollers is packaged. For mill use it is convenient to wind it to form a firm bobbin, usually supported on a wood, paper or plastic tube. The great problem in doing this is to maintain the speed differential between the flyer and the surface of the bobbin constant despite the continuously increasing diameter of the bobbin. The ultimate solution to this problem was Houldsworths differential motion, a beautiful but highly complex and expensive mechanism. It is because of the incorporation of this device in the classical mill speed frame that the latter can only be recommended for small-scale working where competent technicians are available. Attempts have been made to build speed frames for use in rural areas employing simplified versions of the differential motion, but none of these has been successful.

The most practicable solution to the problem is to allow the rovings to fall into rapidly rotating cylindrical cans, the speed of rotation of the cans being just sufficient to put the desired amount of twist into the rovings. The cans themselves may then be transferred to the spinning frame but it is generally regarded as more efficient to wind the roving from the cans on to bobbins before spinning. The construction of speed frames employing this system of roving packaging is well within the capability of rural workshops as also is the construction of simple roller drafting systems suitable for attenuation of slubbings and rovings.

Most post-1940 mill type speed frames are equipped wit. drafting systems more complex than can be recommended for rural use. The reason for this complexity is that, in the interests of labour saving, high and ultra-high draft ratios are being used as a way of reducing the number of speed frame passages needed. For rural use very simple 3- or 4-line drafting is much to be preferred, it will be found to be entirely adequate if draft ratios at a single passage are limited to 4 for slubbings and 6 for rovings. Locally made, power driven speed frames of from 10 to 20 deliveries, with 3-line drafting and rotating-can consolidation of the roving, are used very successfully in small-scale mills and also in centres serving groups of pedal charka spinners.

Manually powered charkas of 6 to 12 spindles often have one spindle replaced by a Danforth throstle spindle driven at a much lower speed. The throstle, which is usually at one end of the row, winds and lightly twists roving made from slubbing which has been attenuated by the main drafting rollers. Although this is by no means 'good' technology it is an effective expedient which is widely used in the spinning of medium counts.

Post-spinning processes

YARN PACKAGING

In many circumstances the most practical way of packaging small-spun spun yarn is in hank form. This is easily and cheaply done and is acceptable to most yarn users. It has the advantage that the use of standard hanks, traditionally packed in standard bundles effectively indicates the count of the yarn and this is a very great convenience in rural and small-town markets. A further advantage is that hank wound yarn can easily be bleached or dyed without further processing.

The only situation in which another form of package is to be preferred is where great wheel-, jenny- or mulespun yarn is going directly to a weaver for use as weft. These methods of spinning are able to produce yarn in the form of a cop, a very compact yarn package which requires no bobbin and is ideally shape to pass through the warp shed either in a shuttle or when hand thrown. This same package is also convenient when preparing warps for weaving.

WEAVING

Modern high speed weaving machines and even the classical 'automatic' loom are essentially unsuited for small-scale working. The common 'non-automatic' power loom, which is in fact automatic in that the basic operations of shedding, picking and beating-up are automatically performed (it is only non-automatic in that an operator is required to replenish the weft in the shuttle from time to time) is suitable for small-scale mill use. It may also be considered for cottage use where power is available. It may even be treadle driven but this is heavy work and it is better to use lightweight versions of essentially the same machine which are specially built for manual operation. These latter are almost as productive as the classical mill power loom and very much cheaper to make. They also require virtually no skill to operate.

Looms of this sort, although they weave good cloth and give high operative productivity, are not the ideal small-scale weaving machine for use in every situation. One important reason is that, although cheap in relation to full scale mill looms, they are not cheap in relation to rural wages. Another, almost equally important, reason is that the nature of the work is sheer drudgery - treadmill work without any of the satisfactions which the exercising of a craft skill can give. There is a great deal to be said in favour of the use of primitive looms which, as they can be easily and cheaply built locally, can be wholly owned by the weaver himself.

The most durable and highly productive form of primitive loom is the 18th century European frame loom. Carefully and substantially built from seasoned hardwood it will give a lifetimes service. It is a viable machine in its original form with hand thrown weft insertion and when fitted with a fly shuttle mechanism it will weave at about half the speed of a simple mill powerloom. This high standard of construction is by no means essential. Very crudely made looms from unseasoned wood work quite well and so also does the pit loom. This latter uses the ground as a frame and the weaving takes place only a few inches above the ground a pit having been dug in such a position that the weaver can sit close to the breast beam with his knees below the cloth.

The need for a frame strong enough to maintain a tension in the warp and permit beating-up of the weft limits the portability of a loom. This is overcome in the back-strap loom. In this arrangement the as yet unwoven end of the warp is anchored to a post or peg driven into the ground. The weaver, seated on the ground, holds the warp taut by means of a harness which passes round his back. The shedding of the warp is done by manipulation of lease rods.

Another type of loom which does not need an integral frame is the warp weighted loom. Here the weaver works standing facing the cloth which, held out to width by a batten, hangs from a tree or, if indoors, from a roof beam. The as yet unwoven part of the warp hangs down below the level at which weft is inserted and is tensioned by weights, often of stone or earthenware, attached to groups of warp threads. This method of weaving is popular with seasonal migratory workers.

As with the weaving process itself, modern mill methods of warp preparation are quite unsuited to small-scale working. There are however, a great many ways of preparing warps and there can be no difficulty in selecting one appropriate to any scale of working. At the highest level of capacity which may be regarded as small-scale it is worthwhile to build a very simple rotary beaming machine and follow this with an equally simple sizing machine. In tropical countries, working at low speeds, it is sometimes possible to dispense with drying cylinders and allow the sized warps to dry naturally passing through the air. If this is not possible a single drying cylinder heated internally by kerosene pressure burners can be used. Alternatively the warp can be dried by leading it through a drying chimney or tunnel externally heated by fire or by kerosene burners. This sort of equipment is suitable for a small-scale weaving mill or for a service centre preparing warps for groups of very-small-scale weavers.

Small groups of weavers, individually working frame looms, with or without fly shuttles, have found it satisfactory to have a commonly owned, very simple beam winder. Each weaver will wind a beam for his own use and then size it progressively in short lengths using a pad or a brush to apply the size, each sized length being left to dry naturally before going on to the next length. Similar groups not owning a winder will have an array of stout pegs fixed in a wall or posts driven into the ground. Each weaver will prepare his own warps by passing yarns round each of the end pegs and passing on one side or the other of the intermediate pegs of the array. When the required number of ends have been wound the assembly of yarns is slipped from one of the end pegs and wound into a compact ball. Lease strings having been inserted before removing the yarn assembly from the pegs the weaver now has a ball warp which is very robust and easily handled.

The length of warp which it is most economic for a weaver is bound up with the amount of fixed capital employed, the rate of cloth production and operative wage rates. In round figures the length appropriate for small-scale power-loom weaving is several hundred yards. For manually operated frame loom weaving a length between 50 and 100 yards is more suitable. For users of more primitive looms the preferred lengths are are very much shorter. So short in fact that it is desirable to make the length a simple multiple of the length in which the cloth will be used. Pit loom weavers are sometimes content to use warps just long enough to weave a single dress length, although it is more common to weave two (or perhaps three) lengths from each warp. These very short warps are easily and quickly prepared needed by winding round small arrays of pegs and then transfer the resulting warp directly to the loom. If sizing is required it is then, with pad or brush, actually on the loom.

Weft preparation also involves consideration of the local relationship between capital costs and wage rates. Where great wheel, jenny or mule spun yarn in cop form is available no weft preparation is needed. Cops use no bobbins and can be used directly in every type of loom suitable for small-scale rural weaving. They can also be used in automatic looms working on the shuttle-change (as distinct from the pirn change) system of automatic weft replenishment. Frame-spun yarn is almost always removed from the bobbins on which it has been spun and is available to weavers only in hank form. It is necessary then for the weaver to rewind it into cop or pirn form.

For small-scale weaving mills using power looms it is worthwhile to use simple power-driven pirn winders. The most widely used type winds from hanks mounted on readily detachable, light swifts. Machines of this sort are easily built in rural workshops with from 6 to 20 deliveries. Typically one operator is needed to tend from 6 to 10 deliveries. Similar machines may be used by groups of individual frame-loom weavers but it is usual here for each weaver to want to prepare his own pirns. This can be done very quickly and easily on a single spindle, driven from a treadled or hand turned wheel. This device, often based on a bicycle wheel, is very cheap to build and is capable of meeting the needs of all small-scale weavers.

FINISHING

Of cotton textiles produced by small-scale methods many will go into service without having been given any finishing treatment. In fact most finishing treatments when properly applied under ideal conditions and closely supervised do not damage the material. It is, however, true that many finishing processes when carried out crudely under primitive conditions can be very damaging indeed. For this reason only the relatively simple processes discussed below are expected to be relevant to small-scale rural industry needs.

1) Yarn dyeing

It may seem paradoxical to regard yarn dyeing, which is done before weaving, as a finishing process but, nevertheless, this is how it is regarded. Colour-woven cloths are generally more highly prized than are prints, and yarn dyeing enables a weaver to produce such attractive fabrics as stripes, checks, ginghams and tartans as colour woven materials. The dyeing of yarn in hank form is a cheap and simple process. The only equipment needed is a vessel in which the dye liquor can be heated and two sticks. The two sticks are held horizontally and parallel just above the vessel. The hanks of yarn are hung from the sticks and immersed in the liquor. By joggling the sticks the hanks are kept moving through the liquor in order to achieve uniform dyeing. When it is judged that the dyestuff is adequately fixed the hanks are removed from the liquor, soaped, washed-off and then allowed to dry.

2) Scouring and bleaching

Before either bleaching or dyeing can be done satisfactorily it is necessary to scour the cloth. If the warp was sized before weaving the first task is to remove the size. This is most easily done by the use of enzymes to break down the starches in the size. Very little equipment is needed. The enzyme is padded on to the cloth which is then rolled up and left in a warm place to allow the enzymes to do their work. If enzymes are not available The size can be removed by a long and vigorous hot wash with alkaline liquors. With the size removed scouring is only a matter of removing minor impurities such as specks of seed coat and waxy, fatty and oily substances by washing. Depending on the quantities of cloth to be treated the cost of the equipment needed ranges from a simple heated vessel and a wooden paddle to a mechanically agitated washing machine such as can be built locally. Where the quantities involved are sufficient to warrant the use of a washing machine it is worthwhile to have also a centrifugal hydro-extractor. This too can be made locally.

With scouring completed bleaching may be begun. It is usual to recognise two standards of bleaching - bleaching for colour and bleaching for white. When bleaching for colour it is only necessary to achieve such a standard of whiteness as will permit subsequent dyeing to achieve bright clear colours. Bleaching to produce a pure white is more demanding but the processing involved is essentially the same but takes longer. Very rapid methods of bleaching are used by large-scale finishers but for small-scale working slower methods are more suitable. A recommended process, which is cheap and reasonably rapid, is to pad the cloth to saturation with a chlorine based bleaching liquor and leave it for a few hours until the desired degree of whiteness has been reached. During this time the cloth should not be in contact with metals and for this reason it is usual to have a tiled cistern into which the saturated cloth can be piled and left whilst the liquor does its work. Immediately after bleaching the cloth must be rinsed, preferably in running water to remove all traces of the bleach liquor.

Where the climate is favourable natural bleaching can be used. This involves nothing more than laying the cloth outdoors to be bleached by the action of direct sunlight. The cloth is left out day and night and , depending on the degree of whiteness required and the intensity of the sunlight the process takes several weeks. The process can be speeded up by damping the cloth with a weak acid solution. Sour milk is sometimes used but dilute sulphuric acid is generally cheaper and more effective. Even after natural bleaching thorough rinsing is necessary

3) Piece dyeing

The equipment needed for efficient piece dyeing depends on the scale of operations. When dealing with very short pieces it is possible to work with nothing more than a heated vessel and a wooden paddle. The cloth is fully immersed in the dye liquor and agitated with the paddle as the temperature is raised and this is continued until the dyestuff is fixed. For longer pieces a larger heated beck is needed and the cloth is passed to and fro through the dye liquor either in rope form or in open width. The latter will generally give more uniform dyeing but, of course, requires a wider beck and effective cloth guiding means. The simplest way of dyeing in open width is the jigger system in which the cloth is drawn, from a roll, through the dye liquor and then rewound on to a second roll on the other side of the beck. This can be done manually or under power with automatic reversals. For dyeing in rope form a winch machine is commonly used. In addition to a beck a winch roller is needed mounted directly above the beck. The ends of the rope of cloth are joined by a temporary sewing to form a loop which passes round the winch roller. Most of the cloth is immersed in the dye liquor and the rotating winch roller keeps the loop of cloth circulating in and out of the liquor. The winch roller need be nothing more than a light wooden paddle wheel. Both the jigger and the winch are machines which can easily be built by local craftsmen and require little in the way of maintenance. Even where pieces are woven short they can be efficiently dyed by jigger or winch by the simple expedient by joining them together, end to end, by temporary sewings.

Although individual weavers, or small groups of weavers, can dye their own cloths it is generally found to be more economic to leave the work to someone specialising in dyeing.

4) Printing

Modern automatic printing machines have no place in small-scale textile manufacture but printing by hand can be a viable business requiring little fixed-capital investment. There are two very different methods of printing which are suitable for small-scale rural use - hand block printing and flat screen printing.

Hand block printing is still widely used where exclusive patterns are required. The pattern to be printed is carved, standing in relief, from the surface of a substantial block of finely-grained hardwood. The raised pattern s smeared with a colour paste and then pressed firmly on to the cloth. It is important to have a good flat surface immediately beneath the part of the cloth being printed as, in practice, it is common to strike the block with a mallet to ensure that the colour will be driven well into the cloth. This procedure can be carried out single-handed but an assistant to move the cloth as the work proceeds is recommended. Where more than one colour of printing is involved a separate printing block is made for each colour.

The screens used in flat-screen printing may be of silk, nylon or fine-wire mesh and are secured in rectangular frames as long as the length of the pattern repeat and as wide as the cloth to be printed. A screen is prepared for each colour needed in a pattern in such a way that where colour is not required the interstices of the screen are sealed with a starch or a varnish. The cloth is laid on a table, a screen is correctly placed on the cloth and colour is applied through the open parts of the screen by means of a brush or a squeegee. As the sharpness of definition of the pattern is limited by the coarseness of the screen mesh, fine detail cannot be printed so well as by block printing. It is, however, adequate for most purposes and, on the credit side is the fact that it is much easier to prepare a screen than to carve a wood block.

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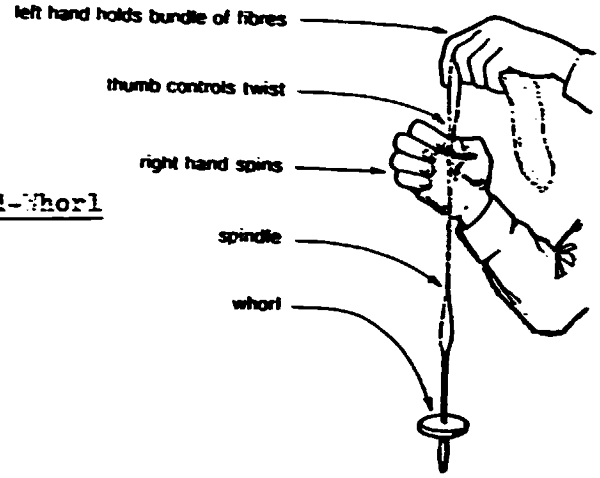
Fig 1

Spinning with Spindle-and-Whorl



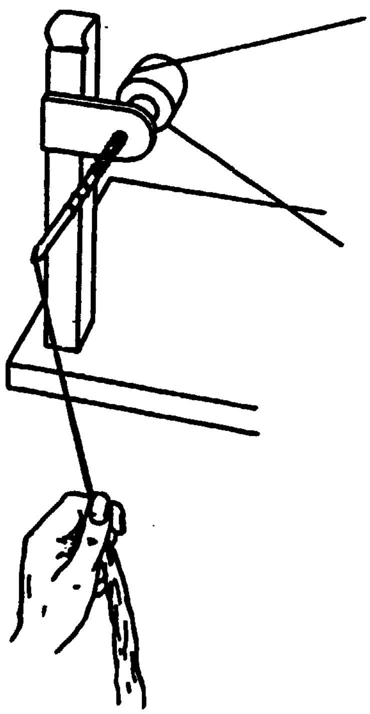
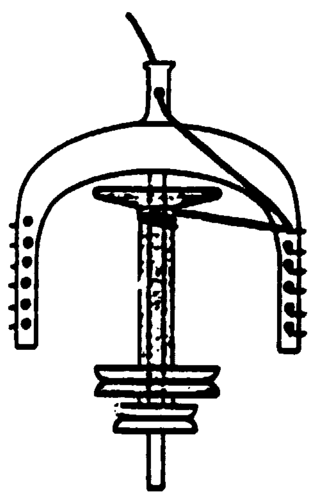


Fig 2

The spinning principle of the Great Wheel and the Jenny

Fig 3

The spinning principle of the Brunswick Wheel and the Water Frame



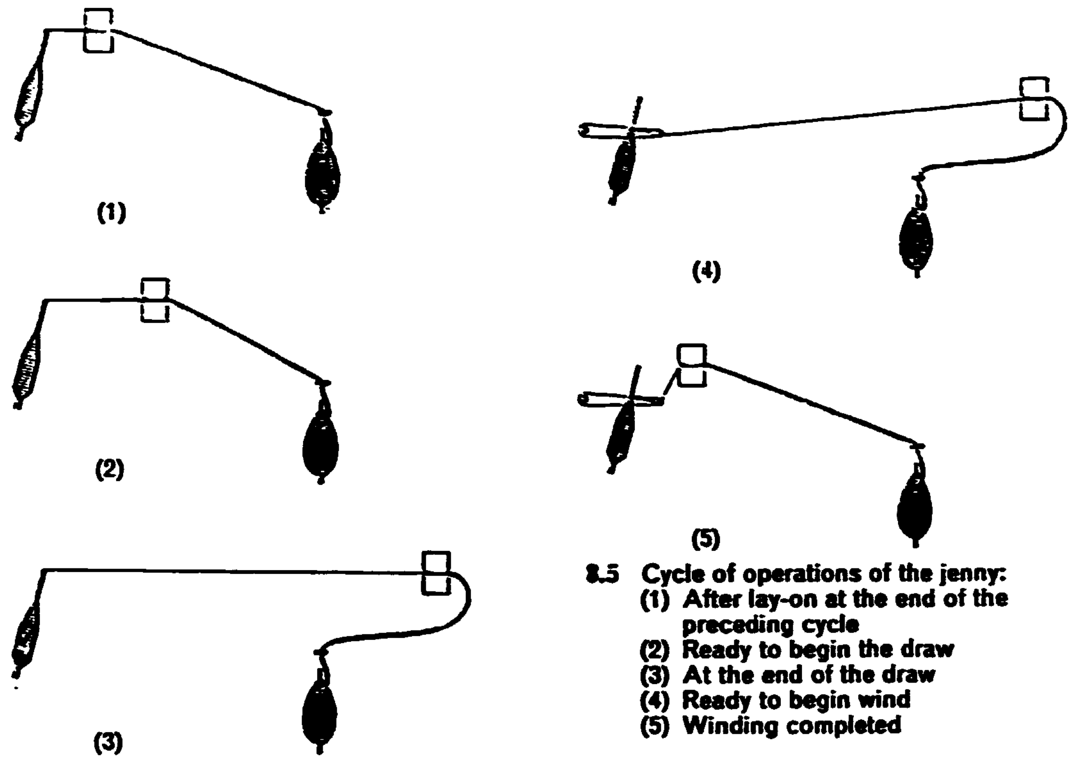


Fig 4 The operating cycle of the Jenny

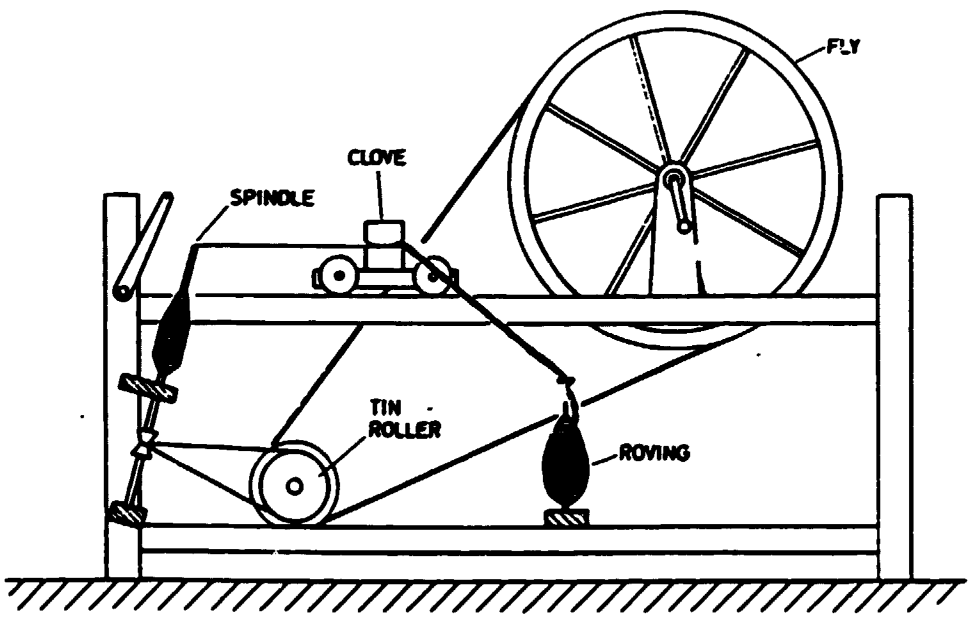


Fig 5 The working elements of the Jenny

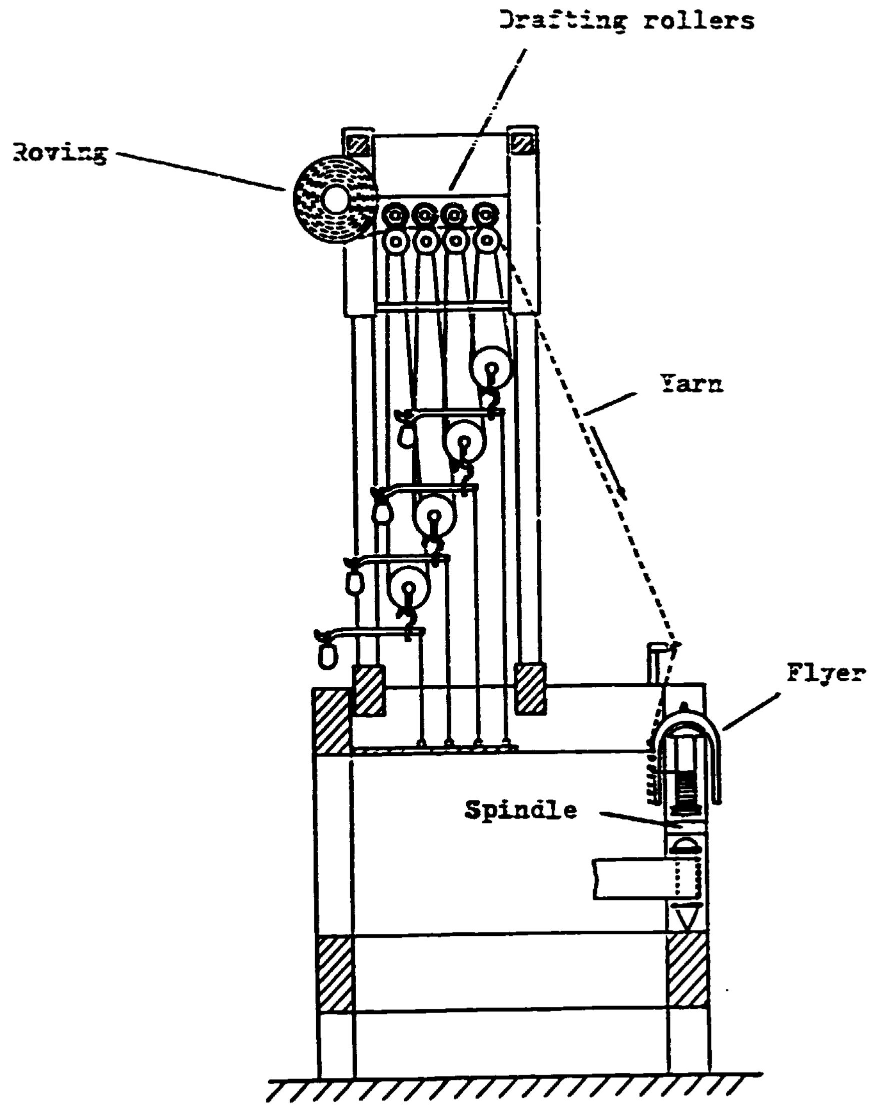
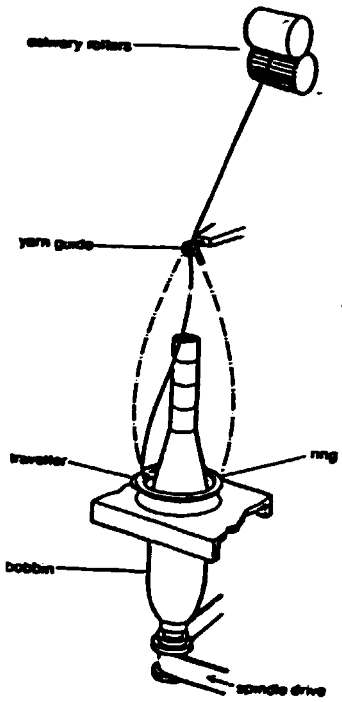


Fig 6

An early form of Water Frame

Fig 7

The Danforth Throstle



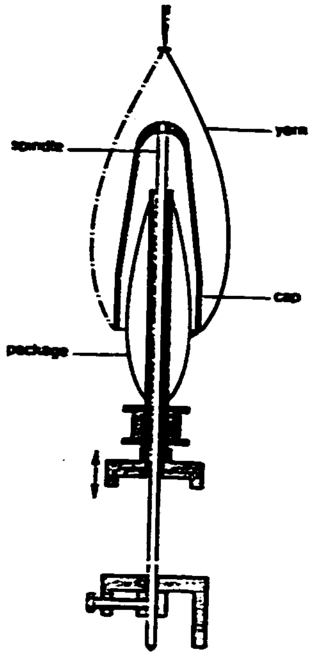


Fig 8

Ring Spinning

Fig 9

The working elements of a common form of Open End Spinner