weaving

by Giovanni Castelli, Salvatore Maietta, Giuseppe Sigrisi, Ivo Matteo Slaviero

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Introduction

I am pleased to introduce the first of a series of four ″Reference Books″ about textile machinery technologies, which the ACIMIT Foundation decided to offer to the Italian textile institutes.

The subjects of this Reference Book are machines, accessories, ancillary equipment and technologies related to ″Weaving″, a sector in which Italy boasts the presence of top–ranking companies offering worldwide a state-of-the-art know-how.

This Reference Book concerning ″Weaving″ will be followed in the year 2001 by three other References Books reserved to ″Knitting″, ″Spinning″ and ″Finishing.

The exigence of realizing these Reference Books originated from a series of meetings which the ACIMIT Foundation – within various initiatives aimed at developing their relations with the educational bodies - decided to start up in co-operation with the headmasters and the teaching staff of the textile institutes.

ACIMIT Foundation had been informed in fact that the editions which are presently used as textbooks in these institutes do not keep up any more with the continuous and rapid technological development characterizing this sector in last years.

Consequently, to comply as much as possible with the learning needs of the students, the ACIMIT Foundation thought it advisable, in agreement with the headmasters of the various institutes, to entrust the realization of the Reference Books to a group of teachers of these institutes, who accepted with great enthusiasm this not easy task.

The Italian textile machinery producers wish therefore to thank sincerely the headmasters and teachers of these institutes, from which they draw precious resources for the development of their own enterprises.

As nothing is born perfect, we shall be sincerely grateful to everybody concerned (students, teachers, company technicians, etc.) for any suggestion and correction, which will enable us to improve our work and make it more and more profitable.

Alberto M. Sacchi, President, ACIMIT Foundation

Acknowledgments

ACIMIT Foundation feel bound to thank the headmasters and the teachers of following Institutes:

- ITIS Buzzi, Prato
- ITIS Casale, Torino
- ITIS Leonardo da Vinci, Carpi (MO)
- ITIS Marzotto, Valdagno (VI)
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- ITIS Carcano, Como
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- ITIS Leonardo da Vinci, Napoli
- ITIS Paleocapa, Bergamo
- ITIS Varese, Varese

Without the helpfulness and the efficient co-operation of the headmasters and teachers of above Institutes, the editing of these Reference Books would never have been possible.

In particular, the draft of the ″Weaving″ Reference Book was performed by following teachers:

prof. Giovanni Castelli	ITIS Varese
prof. Salvatore Maietta	ITIS Varese
prof. Giusepe Sigrisi	ITIS Carcano
prof. Ivo Matteo Slaviero	ITIS Marzotto

who devoted to it time and enthusiasm and deserve the warmest thanks of the ACIMIT Foundation.

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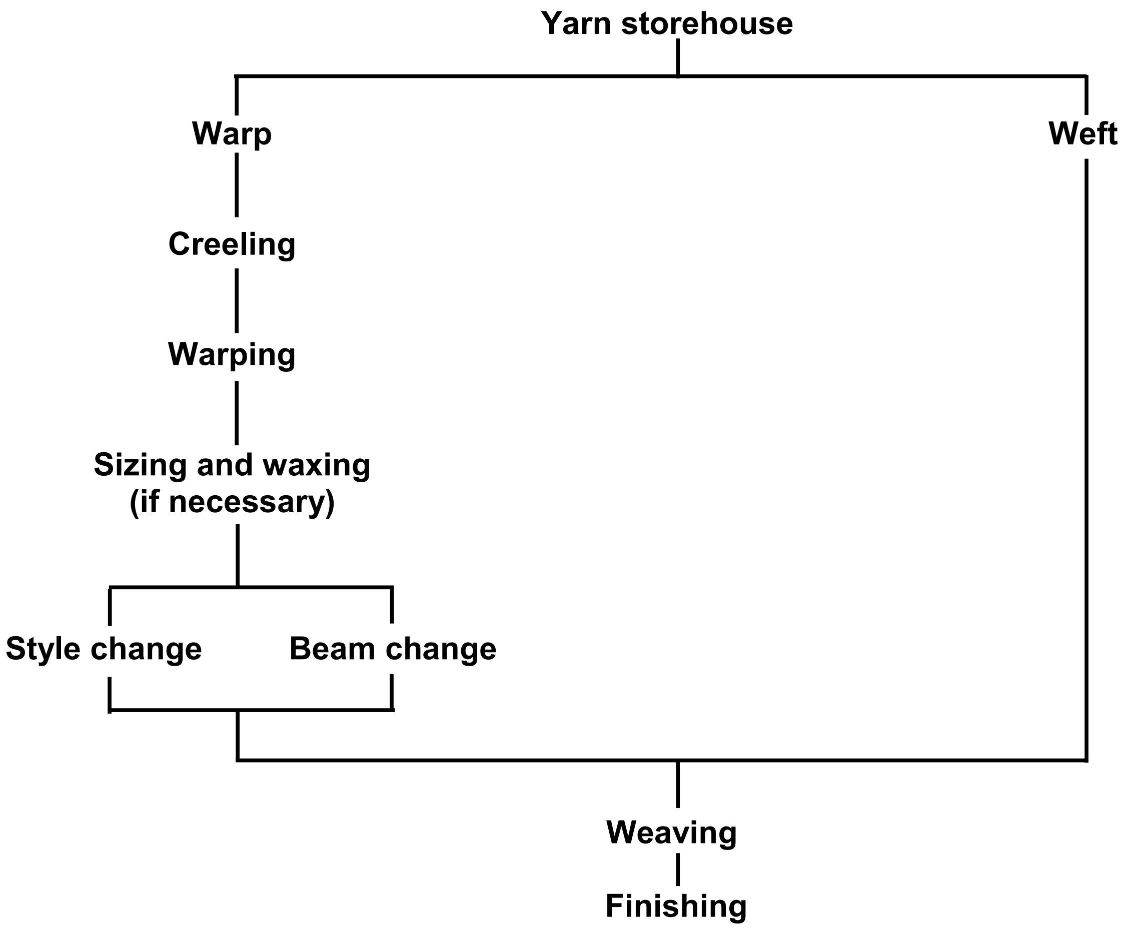
Introduction

A fabric is a flat structure consisting of fibrous products, either natural or ″man made″.
Nowadays there are various technologies suitable to create textiles, which all of them go by the name of fabrics.
We shall deal here exclusively with the technology producing orthogonal fabrics by interlacing together two elements: *warp* and *weft*.
The first element is represented by the threads placed lengthwise in the fabric, while the second is represented by the threads placed in width direction.
The yarn is marketed wound on various types of packages, which generally depend on the technology of the spinning process from which the yarn originates; the most common packages are cones (either cones or bicones, or tubes, or tricones), spools or bobbins, flanged bobbins, hanks and cheeses.
Owing to the specialization trend of modern technology, the weaving industry is supplied today only with ″hard″ packages, with yarn wound on rigid tubes which consequently can be used as such in the weaving process.
Should the type of package not be appropriate, then the first operation to carry out would be rewinding (cone winding), a processing phase which can be considered as the last integration of the spinning process.
Starting from the storehouse, the yarn is subjected to following working sequence until the weaving stage:



Warping

Warping is aimed at preparing the weaver's beam to be set up on the weaving machine. Warping carries out following operations:

- creation, out of a limited number of warp threads (creel load), of a warp composed of any number of threads with the desired length;
- arrangement of above-mentioned threads according to the desired sequence;
- manufacturing of a warp beam with said characteristics.

If the creeling capacity is equal or higher than the number of warp threads, the warping would simply entail the direct winding on the warp beam of the threads coming from the creel. Generally this condition does not take place and, even with creels of high capacity, the number of creeling positions never corresponds to the number of threads, which is always by far higher than the number of bobbins which the creel can contain.
This problem has been solved by dividing the warping operation into two phases:

- 1st phase: unwinding of the threads from the bobbins and their winding on intermediate carriers, till attainment of the required total number of warp threads;
- 2nd phase: simultaneous rewinding of all these threads and subsequent winding on the weaver's beam; the contemporaneity of these two operations is the prerequisite to produce a beam where all threads show same tension and length.

Depending on the kind of intermediate carrier used, the industrial warping process can be carried out according to two different technologies:

- **sectional warping** (conical drum or dresser warping);
- **beam warping or direct warping** (preparatory beam warping).

Creels

Independently of the warping system, the threads are fed from bobbins placed on creels. The creels are simply metallic frames on which the feeding bobbins are fitted; they are equipped with yarn tensioning devices, which in modern machines are provided with automatic control and centralized tension variation.
Moreover the creels are equipped with yarn breakage monitoring systems (fig. 5).
The creel capacity is the parameter on which the number of warping sections or beam s depends; it should be as high as the installation type and planning permit; the usual creel capacity amounts today to 800-1200 bobbins.
Various solutions have been designed to reduce the time required to load the creel and thus increase the warping performance (fig. 1, 2, 3, 4). When standard creels are used, the most cost-effective solution is, provided that there is sufficient room available, to use two creels for one and the same warping machine; in fact, while one of the two creels is used for warping, the other creel can be creeled up again. In this case it is advisable that the reserve creel is equipped with comb holder and that the warp threads are already drawn through the dents of the combs. This way the loss of time caused by creel change can be minimized.

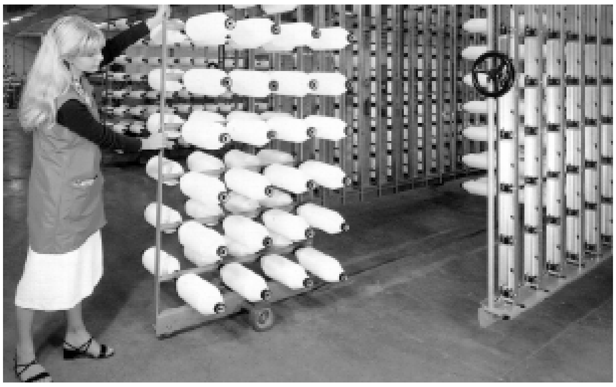


*Fig. 1 – **Mobile creel**: this creel type is similar to the standard creel, but is formed by trolleys which can be taken individually out of the creel. The bobbins are creeled up on each trolley outside the creel. During the creeling up of a series of trolleys, the second series of trolleys is brought back to the outside of the creel to feed the warper. This reduces considerably the waiting time. The mobile creel comes in handy especially when there is insufficient room to permit the use of two standard creels.*

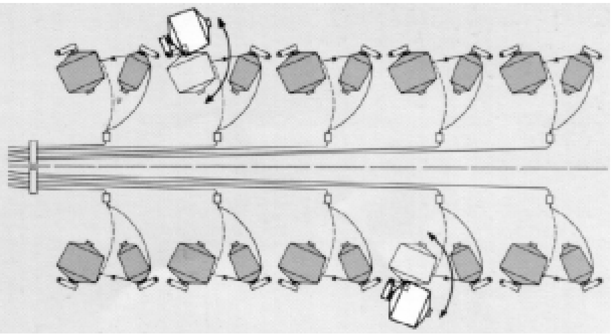


*Fig. 2 – **Magazine creel**: this kind of creel is used when several warps of similar type must be prepared in sequence, that is when large lots of similar yarns need to be processed. Level with each tensioner, two bobbins are positioned: one operating and the other as reserve.*

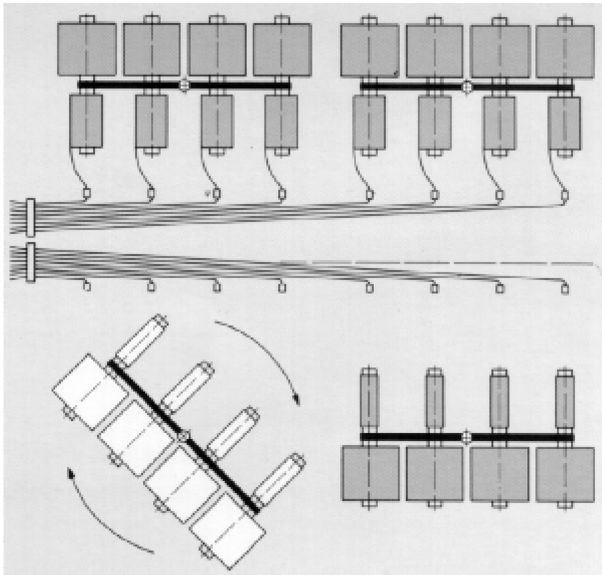


*Fig. 3 – **Swivel frame creel**: this type of creel was designed as a variation of the mobile creel to enable the creeling up of bobbins which, owing to their heavy weight (5 to 25 kg), cannot be pinned on trolleys.*
Each bobbin holder is double-sided: the threads are unwound from one side, while a new series of bobbins is creeled up on the other side.

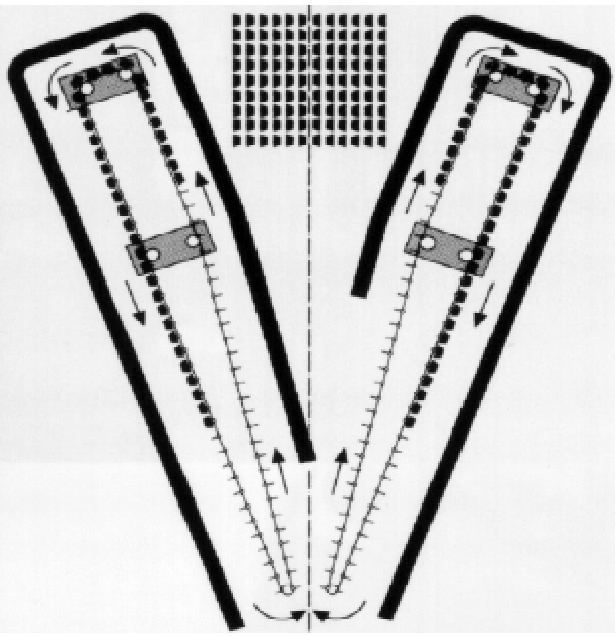


*Fig. 4 – **V-shaped creel**: in this creel type, the creel boards are assembled in form of endless chains. While warping is carried out from the outer sides using the already creeled up bobbins, the subsequent yarn lot can be creeled up on the empty spindles positioned inside the creel. This interior room serves at the same time as storage and bobbin exchange station.*
The yarn lot can be changed by simply pushing a button, which starts the electrically drive of the chains.
The empty bobbins move towards the inside of the creel, the full bobbins towards the outside.

*Fig. 5 – **WARP STOP-MOTION WITH OPTICAL SENSING DEVICE.***

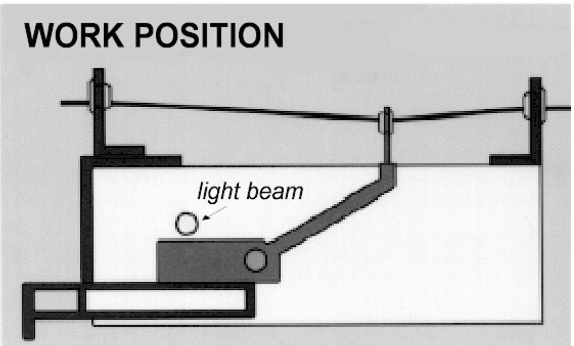


Fig. 5a – During warping the thread supports the drop pin and the light beam is not interrupted.

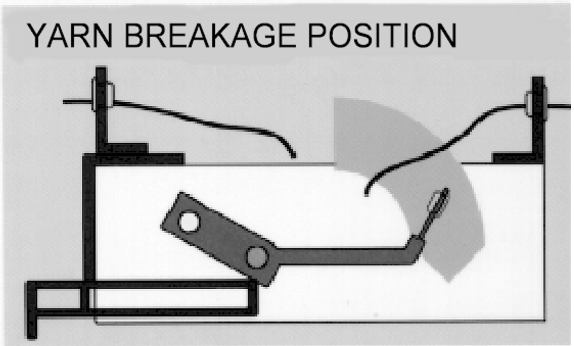


Fig. 5b – At thread breaking or marked thread loosening, the drop pin, being no longer supported, rotates, shades the light beam and alarms the system.

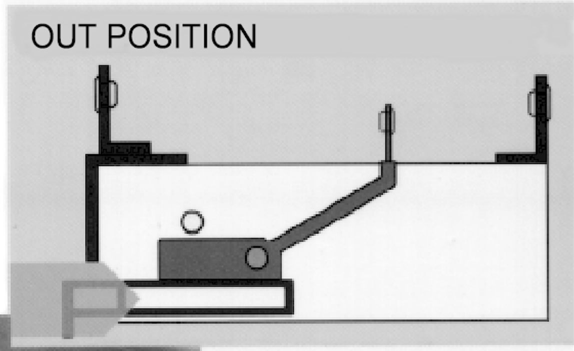
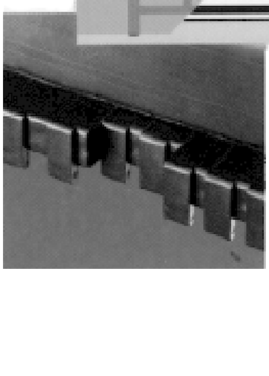


Fig. 5c – The idle threads are cut out by pushing the relevant keys ; the drop pins take up a position which does not interrupt the light beam, thus enabling the working of all other threads.



Keys for cutting out idle yarns.

Sectional warping

As already mentioned, by this warping system several ″sections″ are wound in sequence and parallel to each other on a dresser or on a drum; the warping sections are as many as necessary to obtain, with the available creel capacity, the total number of threads composing the warp.
Sectional warping is cost-effective for short and striped warps (cotton and wool fabrics). The warping speed is about 800 m/min, while the beaming speed is about 300 m/min.
Before carrying out warping, following calculations are necessary:

$$\textbf{Section number} = \frac{\textbf{Total number of warp threads}}{\textbf{creel loading capacity}}$$

If the calculation does not give an exact number, the last section will be produced with a number of threads lower than the other sections, or the number of threads composing each section will be reduced so as to get all sections with one and the same number of threads.

$$\textbf{Section width} = \frac{\textbf{Reed width}}{\textbf{Number of sections}}$$

This way the total number of warp threads will occupy on the dresser a width equal to the width of the weaver's beam on which they will be finally wound.

Example:

total number of warp threads:	10,000
creel capacity:	1,100
reed width (cm):	140

$$\textbf{Number of sections} = \frac{\textbf{10,000}}{\textbf{1,100}} = \textbf{9 + 100 threads}$$

There are two possibilities:
either to warp 9 sections with 1,100 threads each
and 1 section with 100 threads;
or to warp 10 sections with 1,000 threads each (therefore all of them equal) using only part of the creel capacity.

In this last case the result will be:

$$\textbf{Section width} = \frac{\textbf{140}}{\textbf{10}} = \textbf{14 cm}$$

A sectional warping plant is composed of:

Creel
Dresser or drum
Trolley
Warping carriage
Leasing and splitting devices for sizing
Beam carrying chuck

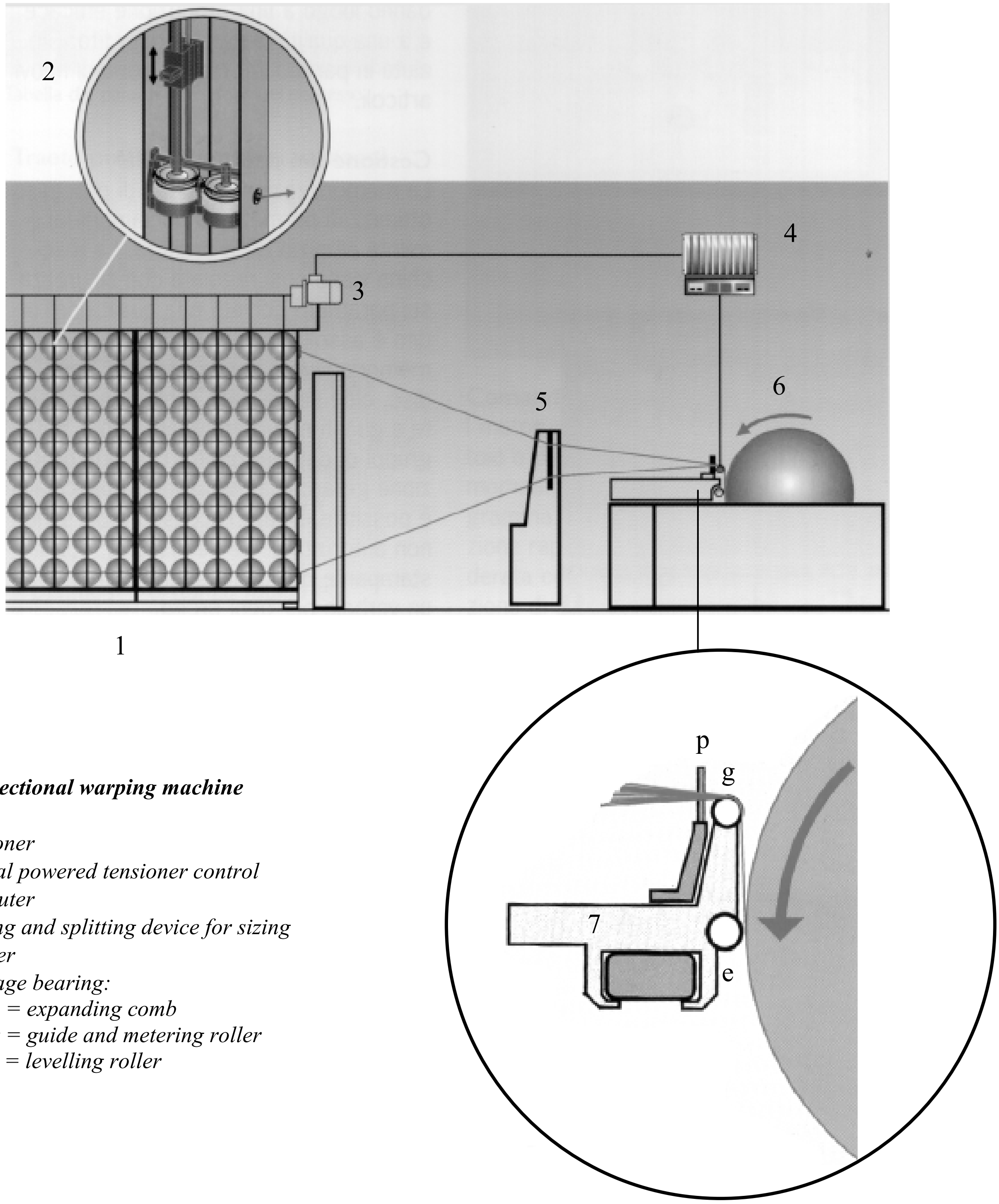


Fig. 6 – ***Sectional warping machine***
1 – Creel
2 – Tensioner
3 – Central powered tensioner control
4 – Computer
5 – Leasing and splitting device for sizing
6 – Dresser
7 – Carriage bearing:
p = expanding comb
g = guide and metering roller
e = levelling roller

We abstain from describing structure and function of the creel, as this topic has been already subject of discussion.

The **dresser or drum** is composed of a big sheet steel cylinder with a precisely turned outer surface which bears at its end a series of slope control rulers (knives), which form a cone with variable taper. There are however also warping machines with fixed taper. The dresser is the creel element on which the threads coming from the creel and guided by the carriage are wound, section after section. The initial taper ratio serves as a support for the various thread layers superimposing each other during warping, and acts therefore practically as a backing flange (fig. 7).

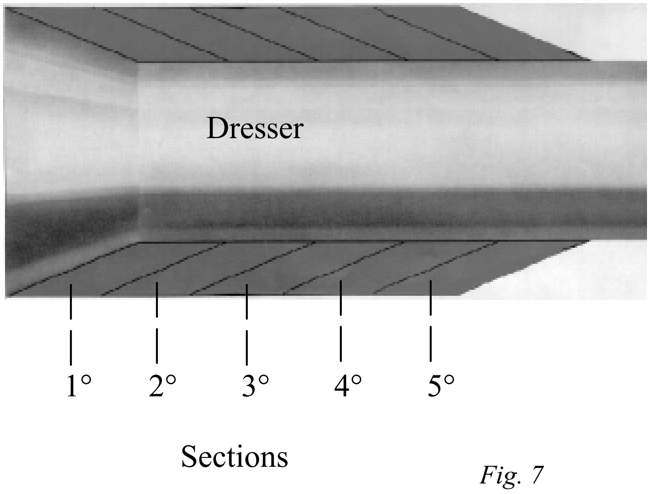


Fig. 7

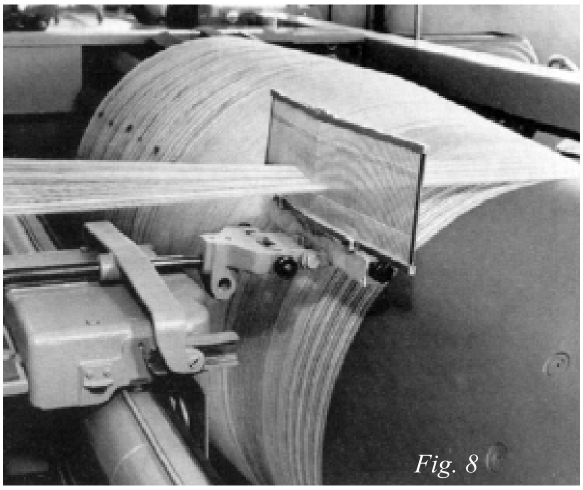


Fig. 8

The **carriage** has a traverse motion and bears the ***expanding or warping comb***, the ***guide and metering roller*** and the ***levelling roller***.
The ***expanding or warping com***b has the task of positioning all threads of each section on a given width, calculated by the already described method. It has in general the shape of an open book with its opening angle adjustable at will (fig. 8).
The ***guide and metering roller*** is situated at very short distance from the contact point of the section on the dresser and provides a precise guide to the section. Moreover it has the task of measuring the tension of the section immediately before the contact point, to transmit this value to the computer. In case that the measured tension is different from the set-up tension, an impulse is given to a central driving motor, which adjusts the value through the tensioners situated on the creel. A uniform thread tension is the decisive prerequisite to obtain a warp having all threads of same length. The correct adjustment of the tensile stress on the section guarantees a constant tension of the threads.
The ***levelling roller*** permits to carry out the warping under low thread tension, and to attain at the same time a compact winding. When processing mono-filament or multi-filament yarns in fine counts which do not stand high compression, it is possible to cut out the levelling roller.
The carriage has two motions: a slow traverse motion parallel to the drum axis, which makes the yarn layers to climb up the dresser cone; this motion, called ***feed*** (fig. 9), permits the leaning of the first section on the drum cone and the leaning of the subsequent sections on the previous sections. The extent of these motions is anyway so small, that the creel stands perfectly still. The second motion enables the carriage to move along the section width at each section change; during this change also the creel (or the warping machine) have to be moved in order to keep the threads as much as possible perpendicular to the drum axis.

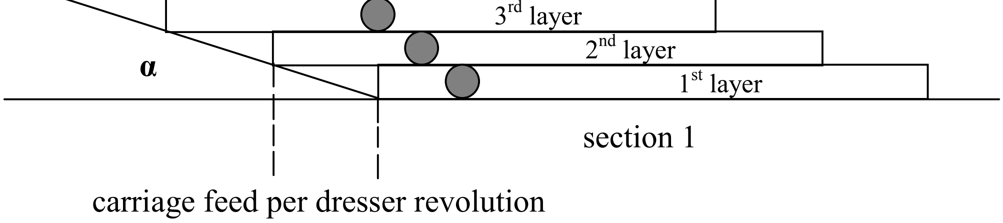
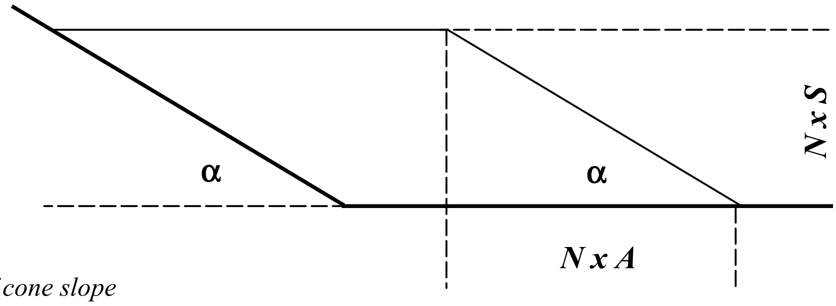


Fig. 9

In the case of ***warping machines with variable taper***, the slope angle is calculated in relation to the set-up feed, to the yarn count and type and to the number of ends per centimeter.
As to ***warping machines with fixed taper***, the moving forward A of the carriage can be calculated as follows:

$$tg\,\alpha = \frac{N \times S}{N \times A} = \frac{S}{A}$$

$$A = \frac{S}{tg\,\alpha}$$



α = *angle of cone slope*
N = *number of dresser revolutions*
A = *feed of the carriage per dresser revolution*
S = *average thickness of the wound layer*

Fig. 10 – Correlation among feed, cone angle and average thickness of the wound thread layer.

The warping machine with fixed taper is started up with a trial feed, which is set up on basis of a known or approximate value, to originate since the beginning a pre-set lateral displacement of the threads.

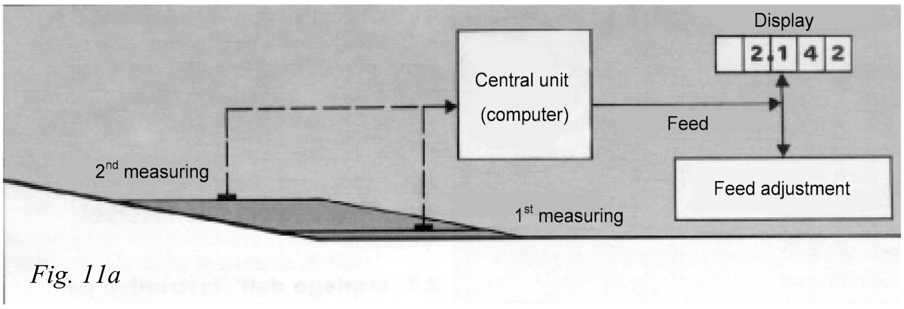


Fig. 11a

Soon after starting warping the first section, the actual thickness of the yarn wound on the dresser is measured and on basis of this value the extent of the feed is automatically corrected. To attain this result, the machine measures two times at the beginning of warping the dresser diameter (through an electronic precision micrometer), that is when the yarn layer reaches a thickness of 2 and 8 mm respectively. As the number of dresser revolutions between the two measurement is known to the computer, this last is in a position to determine the average layer thickness *S*. Moreover, as also the slope angle of the dresser is known, the computer can calculate the exact value of the feed *A*. On basis of this correct feed, the warping machine goes on warping till the end of the first section. The preparation of this first section is stored by the computer and reproduced for all subsequent sections, so that all sections are prepared exactly in the same way (fig. 11a and 11b).

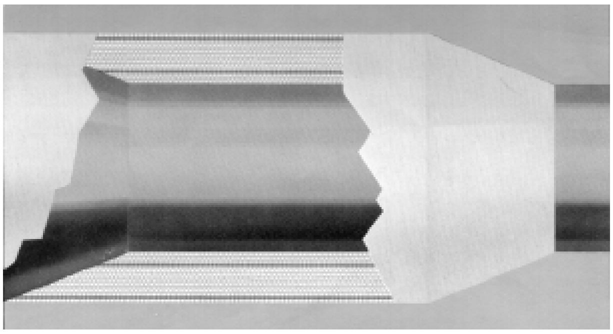


Fig. 11b – Correct winding up of the warp on the drum. Warping with same number of revolutions produces identical thickness of thread layers.

The **leasing device** is composed of:

- a ***leasing rod frame*** which during warping separates the threads into various layers, so that they can go through the subsequent expanding comb without mutual crushing. It serves also to create the room necessary to insert the leasing strings for the sizing operation:
- a ***leasing reed*** to form the shed into which the strings which separate odd from even threads are inserted. To permit this operation, the leasing rod frame is knocked over and two deflection bars bring all the threads to same level. The odd reed dents are interrupted by welding spots, whereas the even dents are completely practicable; the downwards reed movement permits to the welding spots to drag the odd threads downwards. This way the shed for the insertion of the first lease cord is formed. In a second stage the comb moves upwards, dragging the odd threads upwards; thus the second cord can be inserted into the new shed (fig. 12).

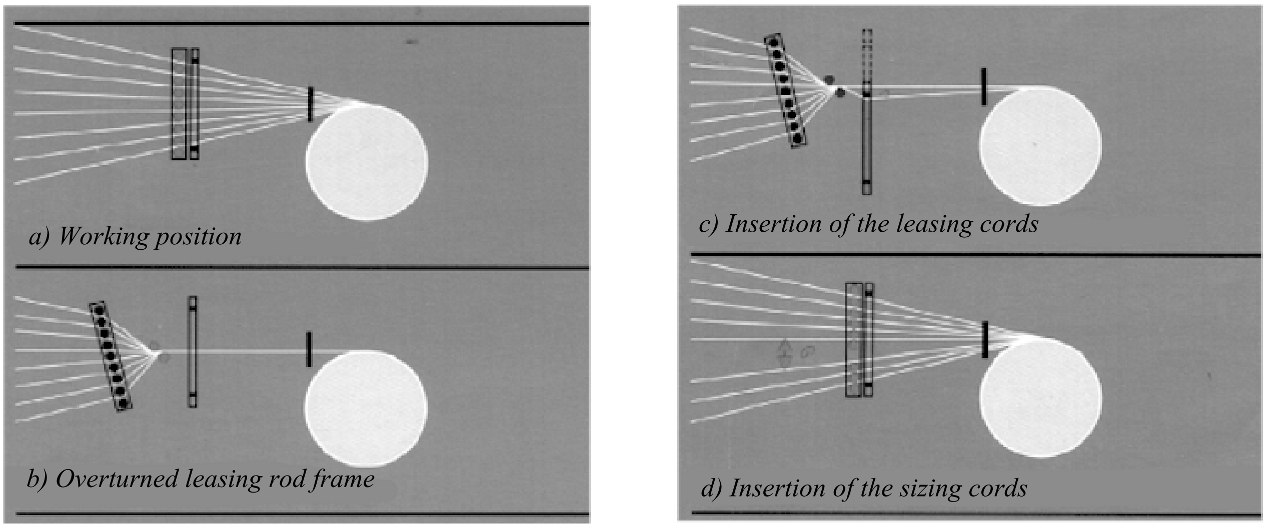
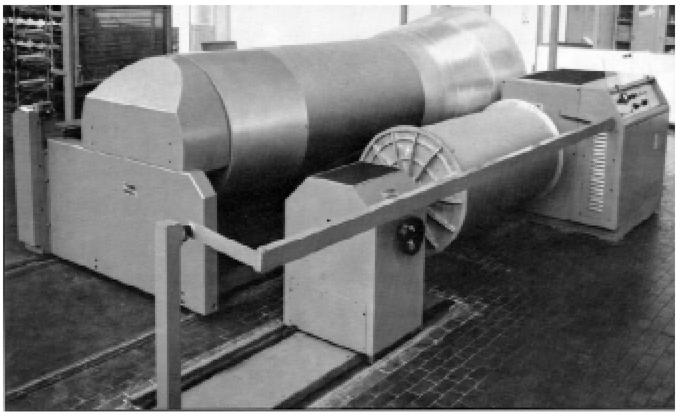


Fig. 12

As soon as all the sections are wound on the drum, the weaver's beam formation is started by unwinding the threads from the dresser and winding them all simultaneously on the weaver's beam placed on the **chuck**. This operation is named *beaming* (fig. 13).
Obviously during beaming the beam moves sideways to compensate the displacement of the carriage during warping and to ensure the exact overlapping of the various layers.

Fig. 13 - Beaming



As regards the driving gears, during warping and beaming two frequency adjusted three-phase induction motors are used. The frequency adjustment is aimed at varying the number of

revolutions, which otherwise would remain constant. The adjustment of the number of revolutions is essential to maintain constant the winding speed of the threads and consequently their tension.
In fact, as the threads are wound both on the drum and on the weaver's beam by direct feeding, the winding speed resulting from the equation:

$$v = \pi n d$$

would not remain constant with the increase of the beam diameter d, if we would not reduce proportionally the number of revolutions n.
Owing to the considerable dimensions of the dresser and to its high inertia, two powerful brakes (band or disc brakes) are installed on both sides of the dresser to minimize the braking distance viz. length.
The brakes permit beaming at high winding tension. During this operation, the braking pressure is automatically adjusted and ensures a constant winding tension along the whole warp length, thus obtaining a beam with uniform winding hardness from the inside through to the outside of the beam (fig. 14).

The warping machines can be equipped with following optional devices:

- **ionization devices**: to prevent the formation of electrostatic charges during the processing of non-conductive yarns;
- **pressure roll devices** (fig. 16b): to obtain a sufficient winding hardness, even operating at low yarn tension;
- **comb inversion devices** (fig. 15): to produce striped warps with symmetrical repeat; this way, as only half of the yarn repeat is creeled up, the change of bobbin position on the creel is avoided;
- **waxing devices** (fig. 16c);
- **motor driven devices for beam loading and unloading.**

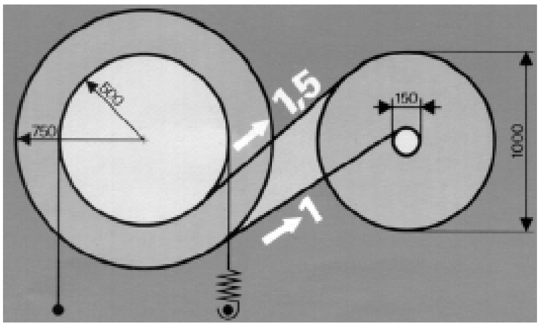


Fig. 14 – Variation of the diameter ratio during beaming. Without the automatic adjustment of the warp tension, this would increase by about 50%.

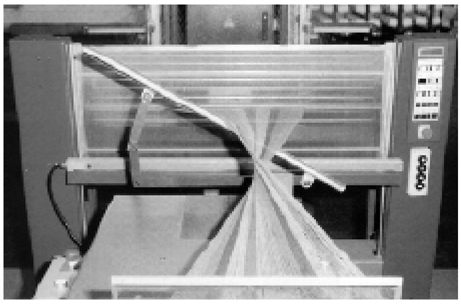


Fig. 15 – Comb inversion.

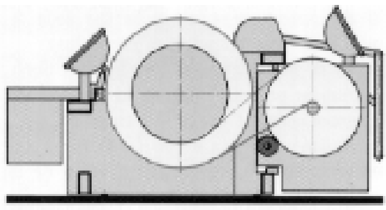


Fig. 16a – Beaming of continuous filament warps without pressure roll device.

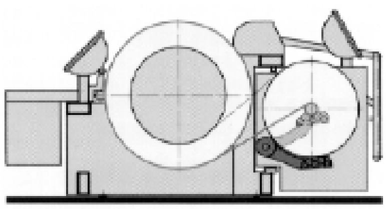


Fig. 16b – Beaming of staple yarns warps with pressure roll device.

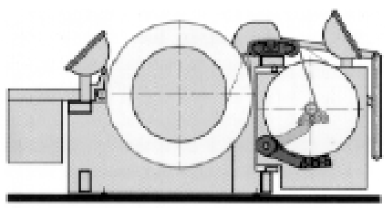


Fig. 16c – Beaming of staple yarns warps with waxing device, with or without pressure roll device.

Beam warping

Beam warping or direct warping is used mostly when several beams of same warp length have to be prepared; also this kind of warping is carried out in two separate stages:

- at first the proper warping takes place: the available threads (creel capacity) are wound on a large cylinder called ″beam ″ and so many beams are prepared as indicated by the result of following expression:

$$\textbf{Number of beams} = \frac{\textbf{Total number of warp yarns}}{\textbf{Creel capacity}}$$

- in a second stage the threads wound on the beams are simultaneously unwound to form the weaver's beam, as shown in fig. 17.

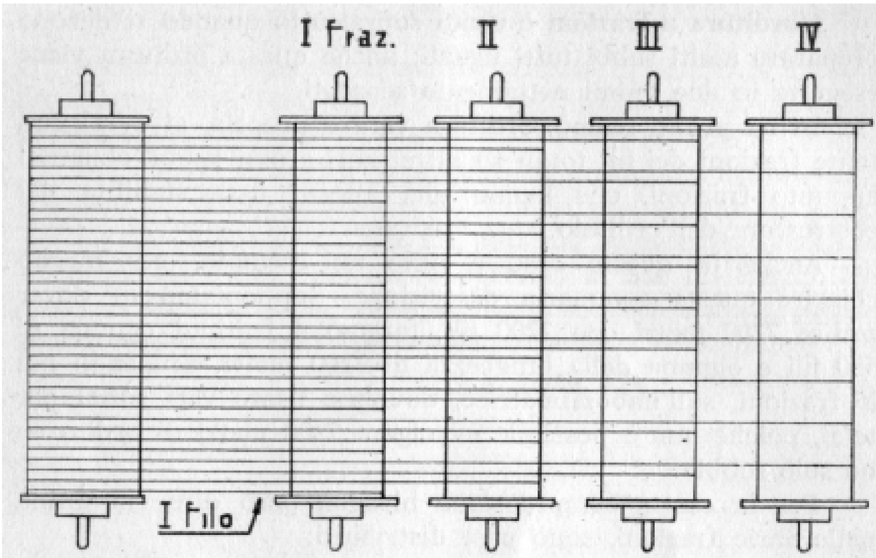


Fig. 17 – Beaming.

The way in which threads are assembled during this second phase shows that the number of the beams should be preferably an integer number.

Example:

number of warp yarns 3,000
creel capacity 560

$$\textbf{Number of beams} = \frac{\textbf{total number of warp threads}}{\textbf{creel capacity}} = = \frac{\textbf{3.000}}{\textbf{560}} = \textbf{5 + 260 rest threads}$$

In this case 5 beams of 560 threads each as well as a beam of 200 threads should be warped. In beam warping it is preferable to have all beams with the same number of threads; therefore if 500 cones are used, 6 beams of 500 threads each shall be warped.

The latest beam warping machines have a very simple design, which results in higher speed and consequently in output increase. The main machine elements are (fig. 18):

- **Creel**
- **Expanding comb**
- **Pressure roller**
- **Beam**.

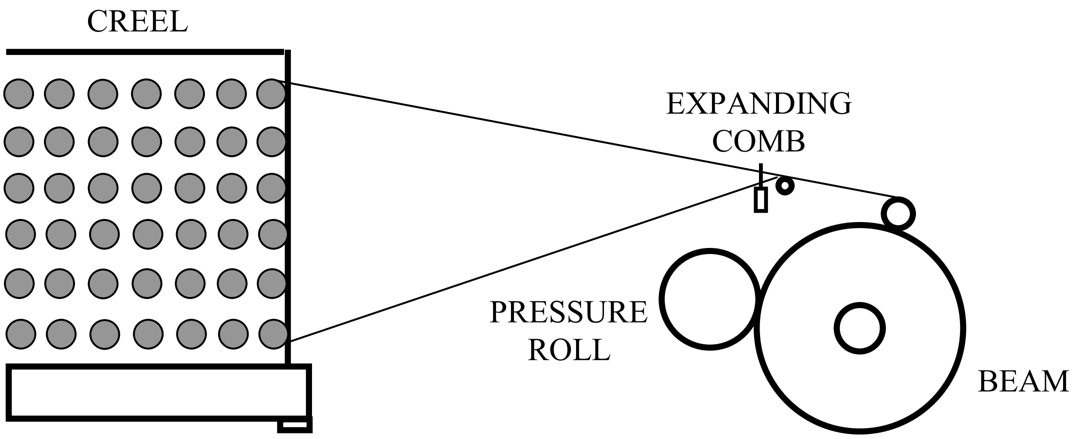


Fig. 18 – Beam warping machine.

Generally for this kind of warping a V-shaped creel is preferred, because it permits high running speeds (up to 1200 m/min) and high productivity.

The **expanding comb** has the aim of placing all threads on a width corresponding to the beam width and the aim of maintaining them in order and without entanglements. The comb has a zigzag shape (fig. 19), which permits its adjustment to the different beam widths. The comb has two traverse motions: a horizontal motion to deposit uniformly the threads on the beam and a vertical motion to avoid the local wear of the dents. A blowing system ensures that the comb remains constantly free from dust.

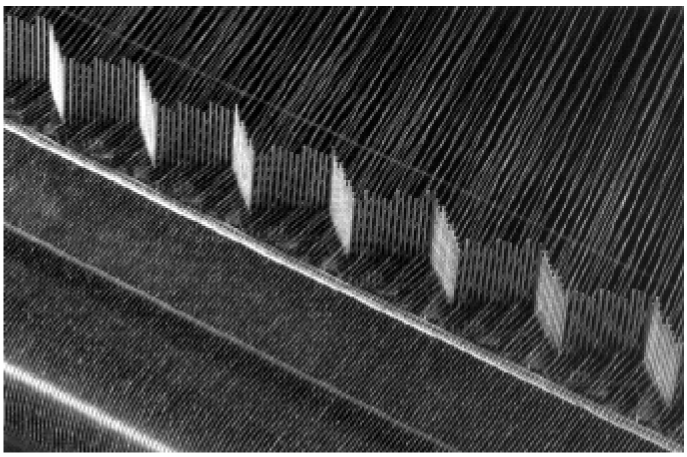


Fig. 19 – Expanding comb.

The **pressure roller** is coated with hard cardboard. The increasing winding thickness of the yarn on the beam moves the pressure roller backwards, thus opposing the resistance offered by the pressure at the set value (fig. 20). Thanks to this compression, perfectly cylindrical beams are obtained. In the braking phase, the pressure roller is immediately lifted by an hydraulic control device.

In case of dye beams, the pressure is set on very low values to enable the production of beams with soft winding, which can be easily penetrated by the dyeing liquors.

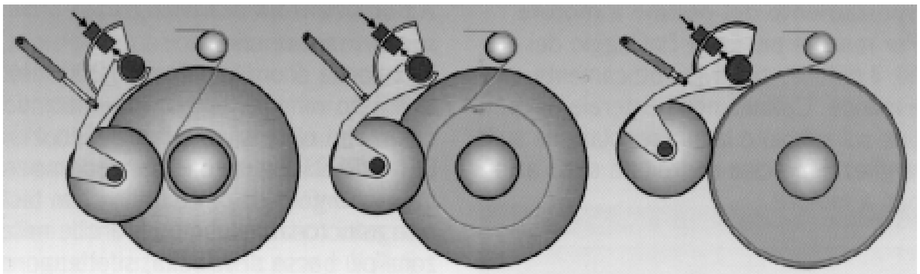


Fig. 20 – The increasing winding thickness of the yarn on the beam moves the pressure roller backwards.

In modern warping machines, the **beam** is driven by a maintenance free three-phase induction motor. As it is a direct drive, in order to ensure a constant winding speed ($v = \pi\ n\ d$) the revolution number is reduced with the increase of the beam diameter, by varying with an inverter the frequency of the feeding current. The beams are driven in some warping machines through pins, in other warpers through self-centering conical toothing (fig. 21) which mesh with the corresponding bevel wheels of the flanges of the beam.

The beams of one and the same warping batch must be wound with absolutely equal yarn lengths. The reason is that, as soon as during the subsequent beaming the first beam runs empty, the batch has to be completed. The excess yarn lengths which remain on the other beams are therefore to be considered as waste.

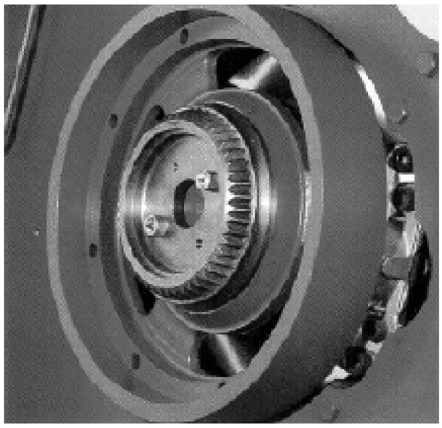


Fig. 21 Conical toothing.

A particular remark for striped warps: while with section warping the warping sequence of each section corresponds (being multiple or sub-multiple) with the final warping sequence (and consequently the array of the cones on the creel does not need to be changed), with beam warping the warping sequences of each beam have to be calculated and fixed in relation to the final warping sequence and to the number of beams (the warping sequence of the beams are generally different from each other, so that the array of the cones on the creel has to be changed). Therefore beam warping is not cost-efficient in case of striped warps.

Direct beaming

As already mentioned, the warps composed of a low number of threads can be wound up directly from the creel on the weaver's beam. The necessary thread guiding elements, including an expanding comb, are mounted on a movable support. The comb has a horizontal traverse motion and is driven by a motor (fig. 22).

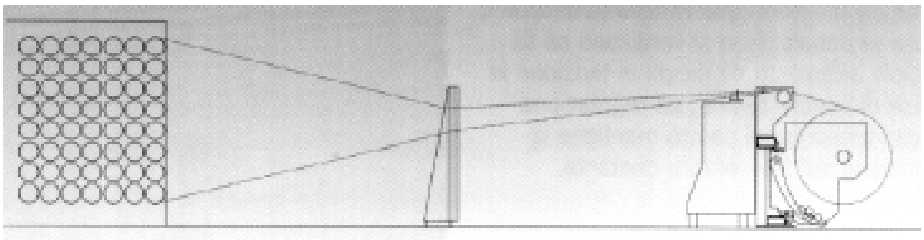


Fig. 22 – Direct beaming.

Sample warping

This warping process, which was developed for sampling purposes, gives full proof of its performances during this production phase of new items. This particular process is composed of several warping operations which wind up a limited thread length and place on the warping width several bands of different colours to get the colour variants of the fabric. This kind of warps can be obtained also by section warping, which however involves a considerable loss of time owing to frequent cone changes and definitely higher investments in raw materials. In practice a cone per colour is sufficient to obtain any required warping sequence. The machine is composed of a small creel where the cones of the warping sequence are placed, by a thread guide which winds up a pre-set number of meters (selectable with a pattern or a control device) taken from the cone according to the thread sequence in progress. The latest solution with revolving creel permits to wind up to 12 threads at a time at a winding speed of max. 1200 meters/minute. Once the winding operation is concluded, the threads are beamed on a weaver's beam which follows the usual production cycle. The machine manufacturers proposed initially two solutions for this kind of warpers: the first solution envisaged a vertical development of the winding blanket, whereas according to the latest solution the threads are pre-wound on a drum before being wound on the weaver's beam. The warp length in this last model varies from 7 to 420 meters; some weavers consider this length as normal for their productions and therefore use this system side by side with the traditional sectional warping machine. It is evident that the correct use of this machine permits to feed the weaving machine in a very short time while minimizing the use of materials and labour, especially if an automatic drawing-in equipment is available upstream.

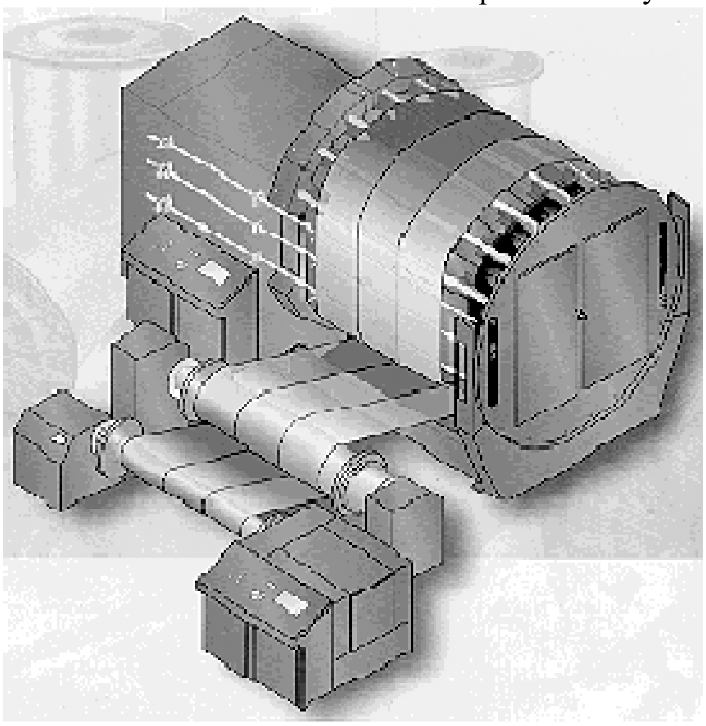


Fig. 23 - Sample warping

Sizing

Sizing is a complementary operation which is carried out on warps formed by spun yarns with insufficient tenacity or by continuous filament yarns with zero twist. In general, when sizing is necessary, the yarn is beam warped, therefore all beams corresponding to the beams are fed, as soon as warping is completed, to the sizing machine where they are assembled. Sizing consists of impregnating the yarn with particular substances which form on the yarn surface a film with the aim of improving yarn smoothness and tenacity during the subsequent weaving stage. Thanks to its improved tenacity and elasticity, the yarn can stand without problems the tensions and the rubbing caused by weaving.
There is not just one sizing ″recipe″ which is valid for all processes, on the contrary the sizing methods change depending on the type of weaving machine used, on the yarn type and count, on

the technician’s experience and skill, but above all on the kind of material in progress. The only common denominator of the various sizing materials is that they have to be easily removable after weaving in order to allow carrying out without problems the selected finishing cycle. The substances used as sizing material are potato flour, starches, glues, fats but also talc and kaolin, when a particularly thick size is requested.
The traditional sizing scheme (fig. 26) is the following:
all beams previously wound on the beam warper are mounted on a special beam creel. The threads are taken off in sequence from all beams and introduced into a vat containing the proper size. The warp enters then a drying unit, where the water contained in the threads is evaporated; this result is obtained by direct contact of the threads with cylinders having decreasing temperatures or by hot air circulation in a room or by radio-frequency operated ovens. These last are a real innovation and operate as follows: the electromagnetic field generated by radio-frequency permits to extract the water contained in the glue, without heating the threads. By avoiding the thermal shock caused by hot air ovens, it is possible to maintain unchanged the chemical and physical properties of the yarn; this is a must when yarns sensitive to heat are processed. It is important to take care that during sizing the threads do not stick together, but remain separate in order not to create problems during the downstream processes. The drying unit is followed by a waxing device which is aimed at increasing the threads smoothness. The process concludes with the winding by an end frame of the threads on a weaver’s beam at a speed up to 650 meters/min. Between the drying unit and the end frame there are lease rods: these are available in the same number as the beams under process minus one and have the function of keeping the threads separate and of preventing that they get entangled and are not wound up with the correct sequence.
A recent variation to the traditional system carries out sizing during beam warping and therefore assembles already sized beams. The advantage is the possibility of sizing beams, each with a warp rate (threads per cm) x times (x = number of beams) lower than the effective warp rate in the weaver’s beam (see scheme in fig. 27).
We wish to draw the attention to the complete indigo vat dyeing line, which permits the production of warps for denim fabrics with a continuous process. These plants enable to dye, size and wind up the beams in just one operation, thus sparing time and floor space.
Figures 24 and 25 show two possible processing lines for the sizing machine.

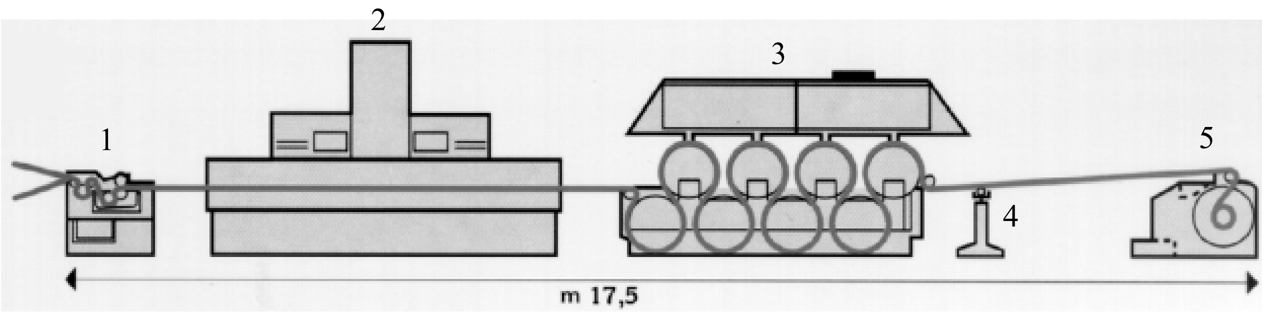


*Fig. 24 – **Sizing machine**: 1 – Size vat; 2 – Radio-frequency oven; 3 – Drum drying machine; 4 – Waxing device; 5 – Beaming.*

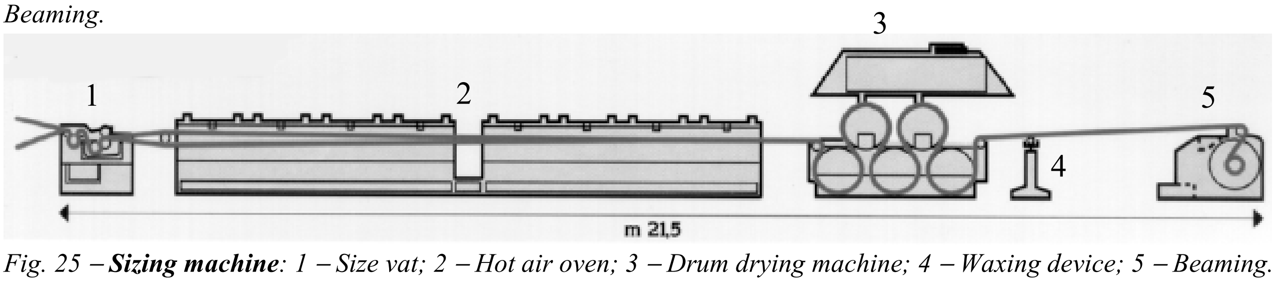


*Fig. 25 – **Sizing machine**: 1 – Size vat; 2 – Hot air oven; 3 – Drum drying machine; 4 – Waxing device; 5 – Beaming.*

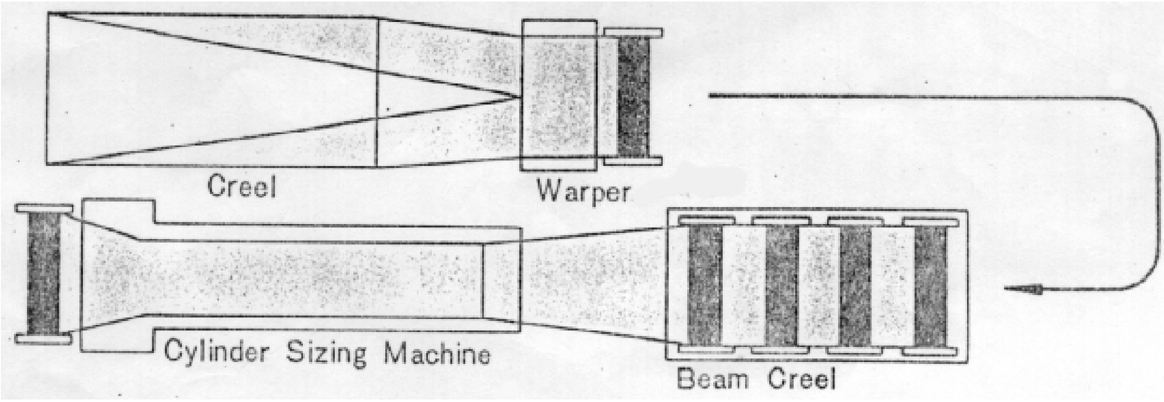


Fig. 26 – ***Conventional sizing****: Creel: contains the cones*
Warper: warps the threads
Beam creel: contains the beams
Cylinder sizing machine: sizes the yarn

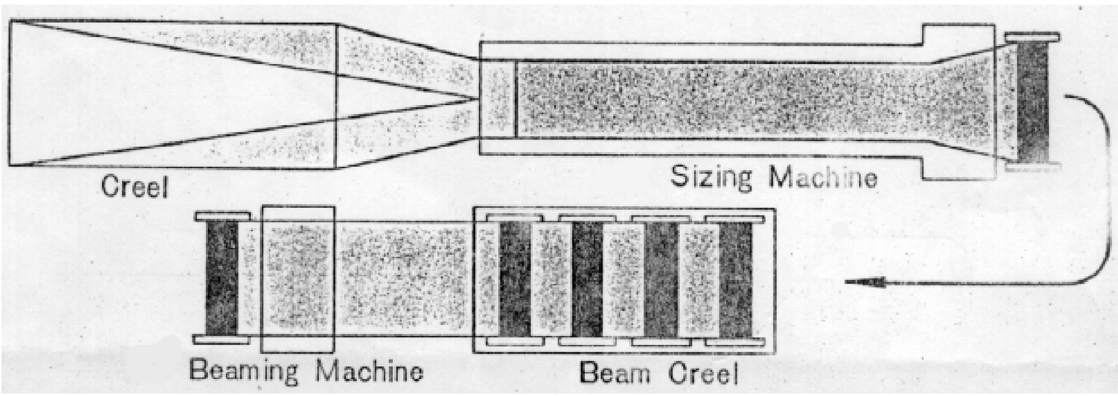


Fig. 27 – ***Unconventional sizing****: Creel: contains the cones*
Sizing machine: warps and sizes the yarn
Beam creel: contains the already sized beams
Beaming machine: assembles the threads of the sized beams and forms the warper's beam.

Preparation of weaving machines

To obtain satisfactory weaving performance, it is essential to have not only a correct yarn preparation, but also an efficient organization which permits to have warps available at the right moment, thus avoiding any dead time with style or beam change. All these prerequisites aim at ensuring to the weaving mills a sufficient flexibility and at permitting them to cope promptly with a variable market demand.
Currently several weaving mills have installed weaving machines which enable to perform the quick style change (QSC), leading to a considerable reduction of the waiting time of the machine.

The following chart presents the possible alternatives for the preparation of the weaving machine:

Weaver's beam store

Style change	**Change of weaver's beam on board the weaving machine**	**Change of weaver's beam beam outside the weaving machine**
Drawing-in	Warp tying-in	Warp tying-in a fixed position outside the weaving machine
Piecing-up		Drawing-in and knot piecing-up
Transport and loading of weaver's beam and harness onto the weaving machine		Transport and loading of weaver's beam and harness onto the weaving machine

Changing style means producing a new fabric style, **weaver's beam changing** means going on weaving the same fabric style just replacing the empty beam with a full beam of same type.
Drawing-in consists of threading the warp yarns through the drop wires, the healds and the reed (fig. 28). Depending on the styles of the produced fabrics and on the company's size, this operation can be carried out manually, by drawing-in female workers

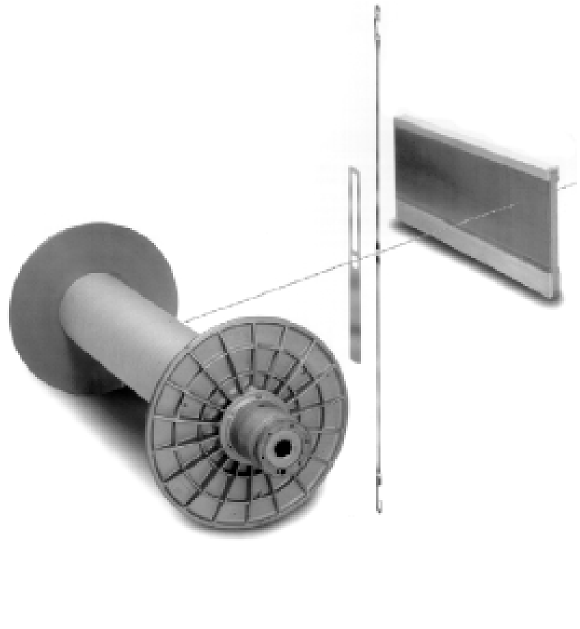


Fig. 28 – Drawing-in

operating in pairs (a time consuming activity which requires also skill and care), or by using automatic drawing-in machines.

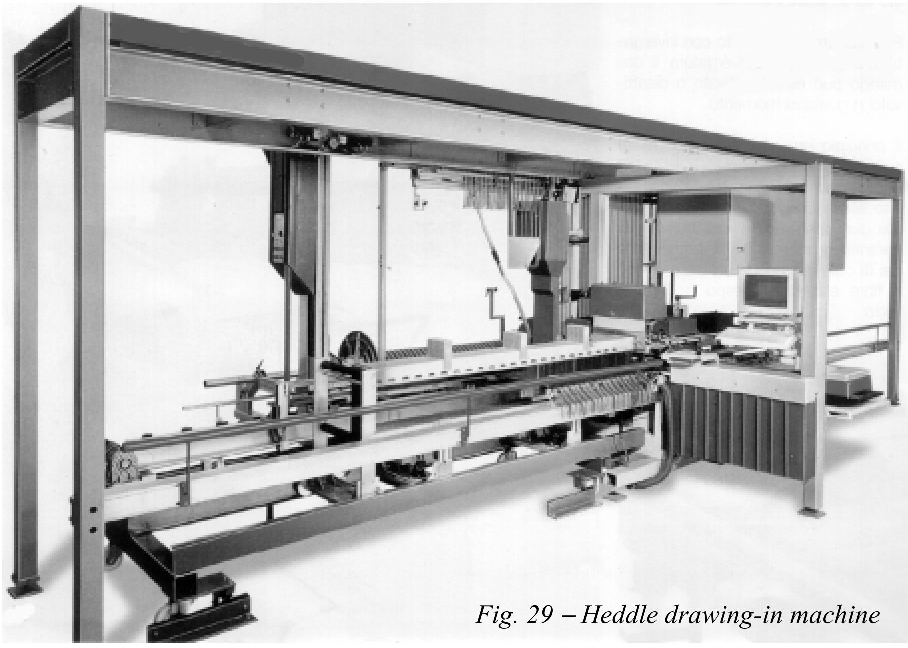


Fig. 29 – Heddle drawing-in machine

Fig. 29 shows one of the most established heald drawing-in machines. The drawing-in begins by placing the weaver's beam, the harness and the row of healds on the proper anchor brackets, then the drawing-in program is typed in on the computer and the machine is started. A sort of long needle picks up in sequence the threads and inserts them with only one movement into the drop wires, the healds and the reed dents, which are selected each time and lined up to that purpose. The computer controls the different functions and supervises them electronically, ensuring the exact execution of the operation and interrupting it in case of defects.

The machine can be used with the usual types of healds, drop wires and reeds and can process a wide range of yarn types and counts, from silk yarns to coarse glass fibre yarns. The drawing-in speed can in optimum conditions exceed 6,000 threads/hour.

Fig. 30 presents another automatic drawing-in machine which carries out same functions as previous machine, however without needing the weaver's beam. In fact it is fed by a common cotton twine which it inserts among the various elements of the warp stop motion, of the harness and of the reed according to the program set up on the computer and under its control and supervision.

Fig. 30 – Automatic drawing-in machine

At the end of the drawing-in, the drawn-in devices are moved on the frame of a knotting station in which an automatic warp tying-in machine joins the drawn-in threads together with the threads of the beam. This operation can be made also on board the loom.

This machine offers the advantage of working always under optimum operating conditions (use of same yarn), independently of the quality of the warp to be prepared and in advance in respect to warping, therefore with higher flexibility. The drawing-in rate can reach 3600 threads/hour. Fig. 31 shows a harness and a reed with already drawn-in threads, ready to be brought to the knotting station.

Fig. 31 – A harness and a reed with drawn-in threads ready to be moved to the knotting station.

The **piecing-up** of the warp yarns (Fig. 32) permits to the weaving mills which are in a position to use it (not many mills at the moment) to simplify and speed up considerably the loom starting operations in case of warps which were drawn-in or tied-up outside the weaving machine. The warp threads are laid into a uniform layer by the brush roller of the piecing-up machine and successively pieced-up between two plastic sheets respectively about 5 cm and 140 cm wide, both covering the whole warp width.
The plastic sheet can be inserted into the weaving machine simply and quickly, avoiding to group the threads together into bundles; the threads are then pieced-up on the tying cloth of the take-up roller.

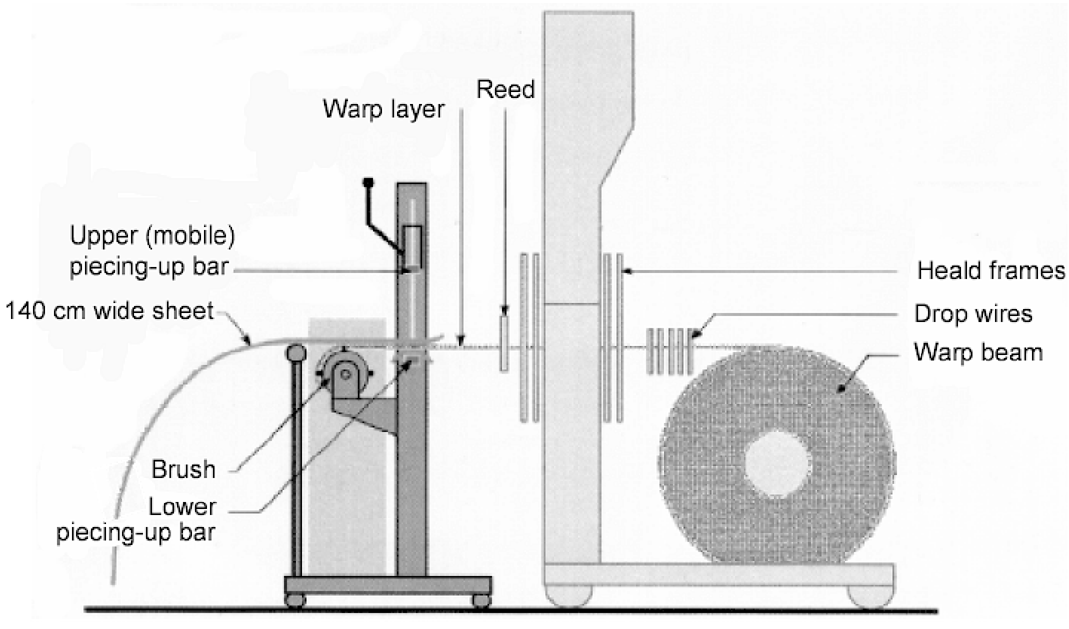


Fig. 32 – Piecing-up

If a new drawing-in operation is not necessary (this expensive operation is avoided whenever possible) because no style change is needed, the warp is taken from the beam store and brought directly to the weaving room, where it is **knotted on board the loom** to the warp prepared with the knotting machine.
As an alternative to the usual knotting on board the loom, the **knotting outside the loom or stationary knotting** of a new warp with an already drawn-in warp can be carried out in the preparation department. The devices bearing the threads of the old warps are taken from the weaving machine and the knotting can be started in the preparation room under better conditions, leaving the weaving machine free for rapid cleaning and maintenance operations.

The stationary knotting, in particular, takes place in following stages:

- Taking out of the loom the prepared beam with the harness
- Transport of the beam into the weaving preparation department
- Fastening of the heald frames and of the reed on the proper frame
- Knotting
- Passing of the knots by proper drawing
- Warp piecing-up
- Temporary maintenance of the new warp with the harness
- Transport of the new warp inclusive of harness with proper carriage
- Loading of the weaving machine and start of the weaving process using plastic sheet (fig. 34)
- Weaving

The automatic knotting machines can process a wide range of yarn types and counts at highly reliable and rapid operating conditions (up to 600 knots/minute), with mechanical or electronic control on double knots and on the sequence of warp patterns in case of multi-coloured warps. Fig. 33 shows a knotting machine in operation on a warp with colour sequence, tensioned on the proper frame.

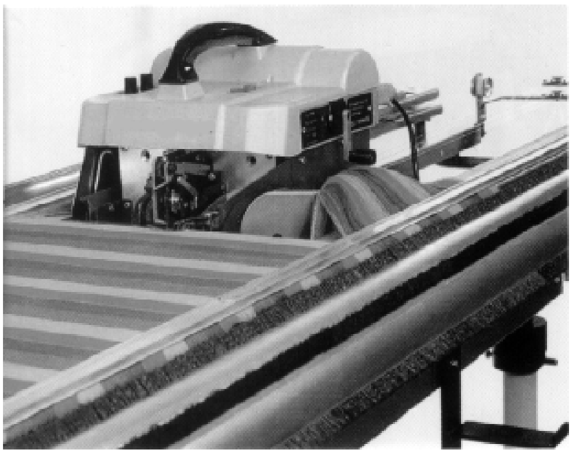


Fig. 33 – A knotting machine in operation on a warp with colour sequence, tensioned on the proper frame.

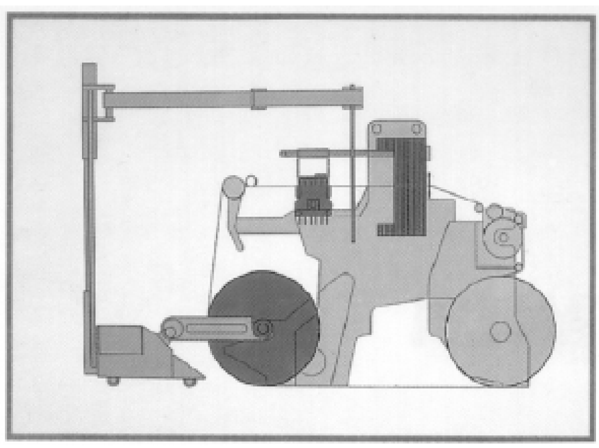


Fig. 34 – Harness loading in the weaving machine.

Weaving machines

General remarks

Actually the research work on the shuttle loom was dropped in the first half of the 70's, with the arrival on the market and the prevalence of systems using for weft insertion other ways than the shuttle. The new shuttleless machines are simply called ″weaving machines″, this term implying looms working without shuttle.
The weaving machines present following advantages over traditional looms:

1. Total elimination of any spooling operation

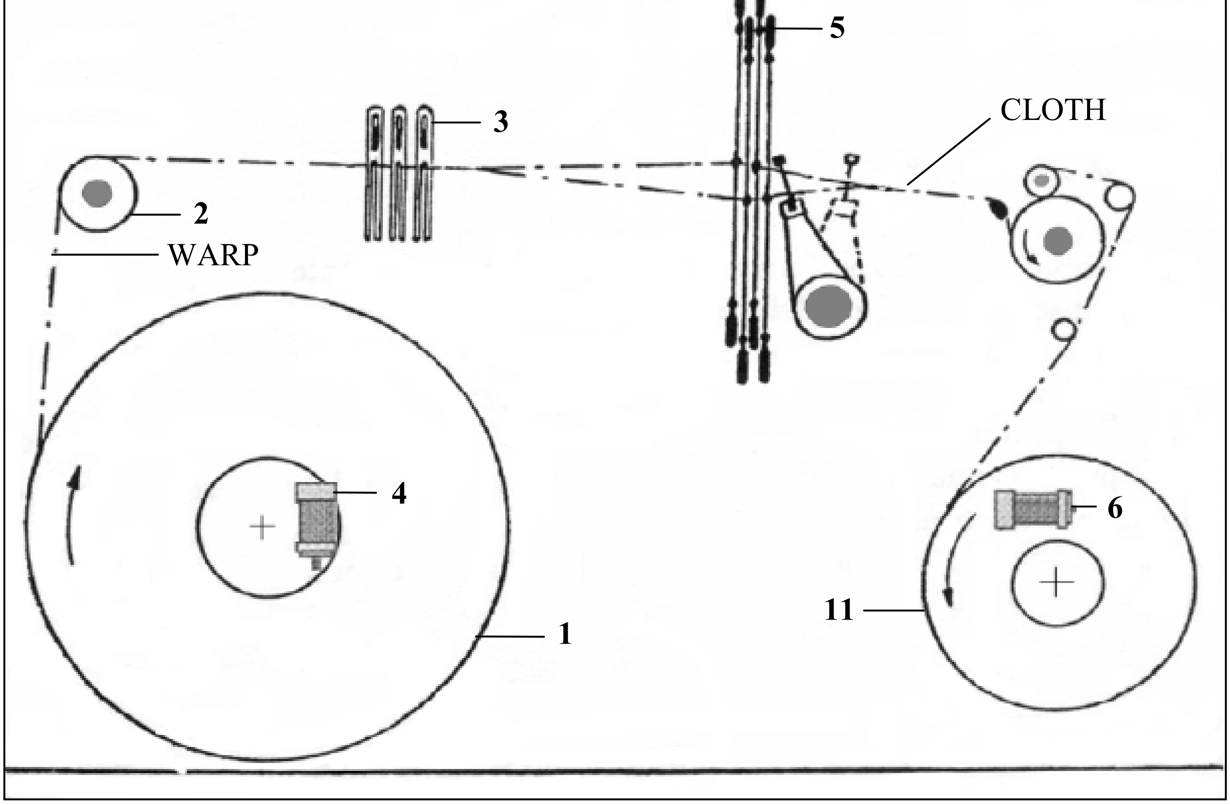
2. Production increase, thanks to the fact that these machines can work at high speed, owing to the reduction or elimination of moving masses

3. Reduction of the shed size, therefore lower tension of the warp threads and consequently reduction in the number of yarn breaks

4. Noise reduction thanks to the elimination of the shuttle pick

5. Automation of various devices.

Fig. 35 – General scheme of a weaving machine.



The warp threads wound on a beam (1) are bent on the back rest roller (2), support special drop wires (3), pass through the healds (5) and through the dents of the reed (8) fastened to the slay (7), along which the vehicle transporting the weft runs (9). The fabric produced is then drawn by a take-down roller(10) and wound on the cloth beam (11).
Fig. 35 shows also the motor driving the warp let-off (4) and the motor driving the fabric take-down (6).

Classification

On the basis of the system used for weft insertion, the weaving machines can be divided into:

A) machines with mechanical weft insertion system:
-by rigid rapiers
- by flexible rapiers
- by projectiles
B) machines with non-mechanical weft insertion system:
- by jets of compressed air
- by jets of compressed water

Furthermore the machines can be divided into:
A) mono-phase weaving machines (inserting one weft at a time)
B) multi-phase weaving machines (inserting several wefts at a time)

Rapier weaving machines

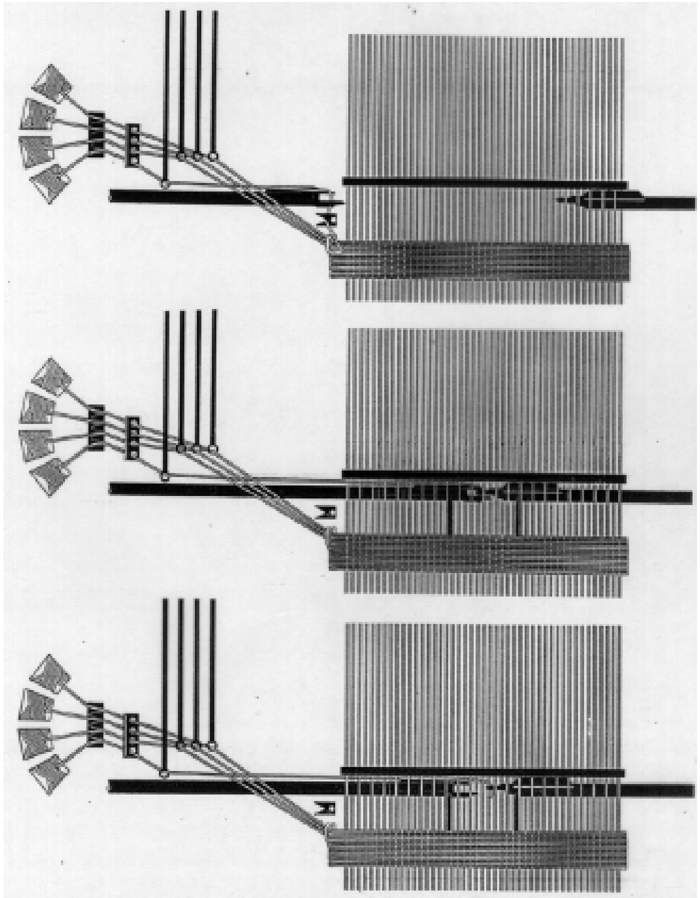
The rapier weaving machines are the most flexible machines on the market. Their application range covers a wide variety of fabric styles. Their present **weaving speed of about 600-700 strokes/min** is the result of the use of a state-of-the-art construction technique, characterized by the use of gear sets without plays and by minimum vibrations of the reed, the slay and the heald frames.

Rapier insertion system

The weft, which is under constant proper control, remains connected to the cloth as a consequence of the previous insertion (or it remains blocked under the temple in the other cases) (fig. 36). At the right moment the selection gear acts in a way, that the end of the weft is caught by the bearing rapier 1 mounted on a flexible tape or on a rod and at the same time is cut by shears on the selvedge side. The weft, after adequate braking, is transported to the center of the shed, where the bearing rapier meets the drawing rapier 2, which takes over the weft thread and, while holding it by its end, transports it back to the opposite side, where the rapier leaves it free, thus completing the insertion.
The weft exchange between the two rapiers in the middle of the shed can take place in two different ways, that is:

- **negative system**
- **positive system.**

Fig. 36 – Working principle of a rapier weaving machine.



Negative rapier exchange system

Here the taking rapier holds the weft tight between a clamp, which is pressed by a spring, and the underlying fixed part. In the middle of the shed, when the rapiers cross each other, ***the tapered end of the receiving rapier penetrates into the sliding channel of the carrying rapier and, during the back motion, hooks the weft thread and slips it off from its position under the clamp of the bearing carrier.*** This causes the clamping of the weft yarn under the clamp of the drawing rapier the more firmly, the higher is the resistance which the other clamp opposes to the thread slipping off. The adjustment of this force depends in principle on the yarn type and count. Also the clamping of the weft at the beginning of the insertion takes place in this case with a negative system, that is without units controlling the rapier's clamp, while the clamping of the weft depends on the adjustment of the thread cutting moment by the selvedge shears; on the contrary the release of the thread at the opposite by the drawing rapier takes place with a positive system, through the opening of the clamp produced by a tooth which presses the clamp's back profile **b**, thus overcoming the opposition of the adjustable springs **m**. In the case of the carrying rapier, this action serves instead to clean the clamp through suction.

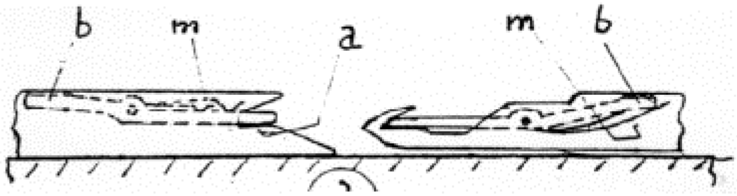


Fig. 37 – Negative rapier exchange

Positive rapier exchange system

When the rapiers cross each other in the middle of the shed, ***two controlled small levers*** rising from below the shed cross the threads of the lower shed and ***set in motion the clamps of the rapiers***. Some control cams, which are roperly timed, regulate their movements.
The sequence is the following: as a result of the pressure of lever 3, which overcomes the force of the closing springs, the clamp of the receiving carrier 5 is opened and can thus get hold of the yarn presented by the carrying rapier. The punch 3, which is driven by its cam 1, releases the clamp of the receiving rapier, which can thus catch the end of the weft. At this point the lever 4, controlled by cam 2, causes the opening of the carrying rapier 6, which thus releases the weft. Now the rapiers begin their back movement again.

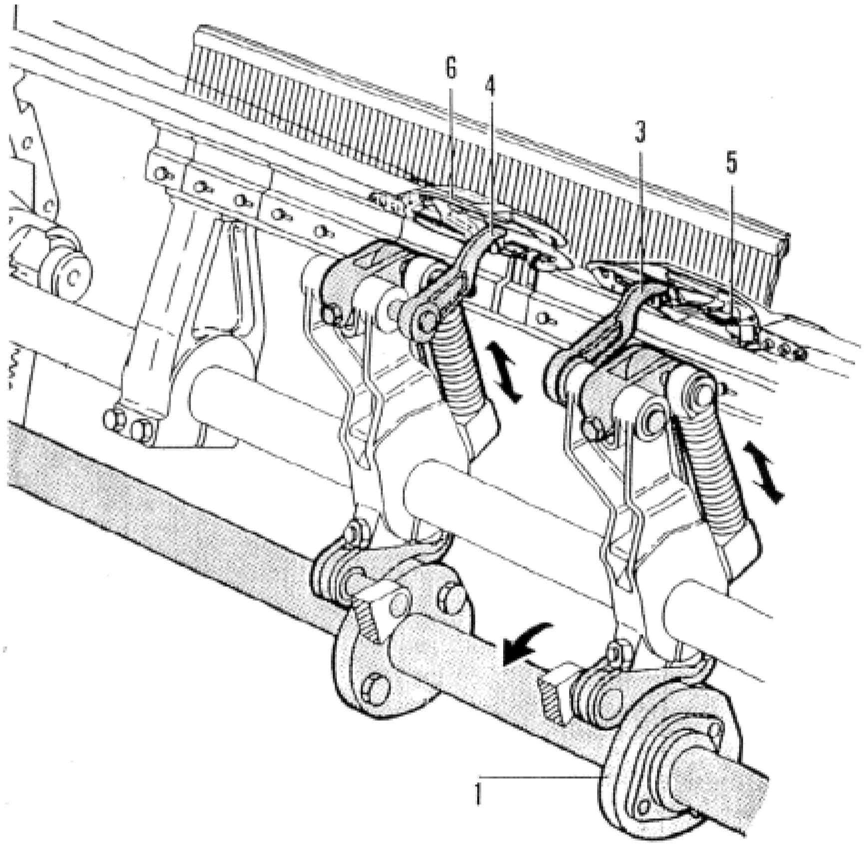


Fig. 38 – Positive rapier exchange

During the rapier exchange it is therefore necessary that the displacement of the rapiers take place at very low speed. Of course, when the exchange between the rapiers is positively controlled, also the initial taking and the final release of the thread outside the shed take place with positive system.
The positive system has the advantage of a higher versatility as far as the range of the usable yarn counts is concerned, but on the other hand has lower performance in terms of running speed and has a more complex construction.

Rapier support

The manufacturers of rapier machines had to choose whether to use as a support for the rapiers ***(rigid) rods or (flexible) belts.***

The rods have the advantage that the support and the rapier move along the shed without any contact with the warp, which fact is important especially when delicate yarns are to be processed.
The rods are rigid supports, each one provided at its bottom with a rack gear which meshes with a control toothed wheel. They must be sufficiently strong and rigid to ensure stability and precision to the rapiers also during their difficult working conditions (alternating motion), notwithstanding the lack of any support and guide unit inside the shed. Their advantage in respect to the belts is

that they ensure the absence of any contact and interference with the warp thread during weft insertion. Owing to their rigidity, they need however more floor space, considering also the presence of the containers at both sides of the machine and the stability problems due to increasing working speeds and heights.

The belts are flexible supports made of composite material, which are equipped in the middle with a series of shaped holes through which they mesh, like a chain, with the driving toothed wheel. The belts, as they are flexible, do not protrude to the outside, but are bent at 180° and collected in the room below, so that they do not increase the space requirements of the machine. The flexible belt system is the solution preferred by most manufacturers and in particular by all Italian manufacturers. There are at the moment two trends. Some manufacturers mount on the reed bracket small shaped pins which create a slide guide for the belts; this guide prevents any anomalous movement of the belts, thus ensuring a stable and exact motion of the rapiers, at any height and speed. Their shape has been designed in order to minimize their interference with the warp threads, even if this fact cannot be guaranteed in all circumstances. Also small guide pins

Fig. 39 Floating guide

of special shape have been adopted; these pins, besides guiding the belts, keep them raised together with the pertaining rapiers, thus avoiding the sliding on the threads of the bottom shed during weft insertion.
Other manufacturers gave their prefrence to a different technical solution. In fact they use wider belts, which oppose an adequate rigidity to the side thrusts and consequently ensure stability and precision in the transport of the rapiers, preventing the presence of belt guides inside the shed and minimizing the abrasion on the warp. Moreover the belts are provided in their initial part with a rib which increases their rigidity, so that the lateral belt guide opposes, outside the shed, the bending moment originated during the acceleration phase. Belts and rapiers slide however on the threads of the bottom shed, causing inconveniences under particular conditions.

Driving gears for belts or rapier rods

To transform a uniform rotary motion into an alternating motion, all kinds of gears are used. Among these gears, the cam motion system is the most used as it is possible to study the cam profile in order to obtain an accelerating movement of the rapiers which permits the most delicate handling of the yarn. This fact is particularly important during the critical moments of the thread clamping at the beginning of the cycle, during the rapier exchange in the middle of the shed and during the release of the weft at its exit from the shed at the opposite side. In all these cases the weaver tries to operate at the lowest possible speed rates.

We give hereunder some examples driving systems for flexible rapiers.

A manufacturer uses in his machines the following disk cam system with complementary cam profile (fig. 40): the rotating shaft 1 carries fixed a couple of disk cams with complementary profile 2 (the other couple of cams serves to move the reed) which transmits, through a roller cam follower 3, a swinging movement to a lever with adjustable arm (not visible in the figure), which lever is linked to the connecting rod 4. This last transmits the swinging motion to the block 5, mounted eccentrically on shaft 6, which by a system of side gears and planet wheels converts the movement into the alternating rotary movement of a crown wheel with pinion 7 and of the toothed wheel 8. The flexible rapier belt, which is driven by this wheel, moves on a straight level and transforms the alternating rotary motion into a straight rotary motion. Of course a similar gear carries out the control of the other rapier.

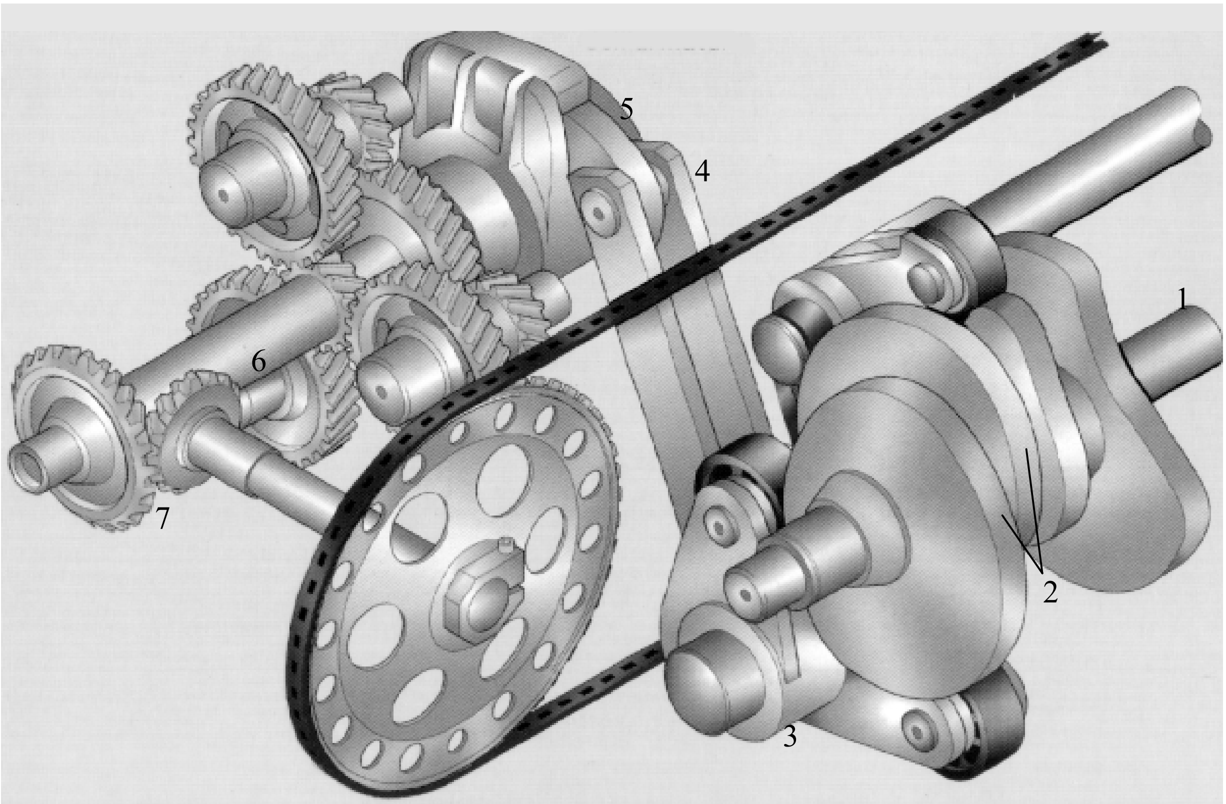
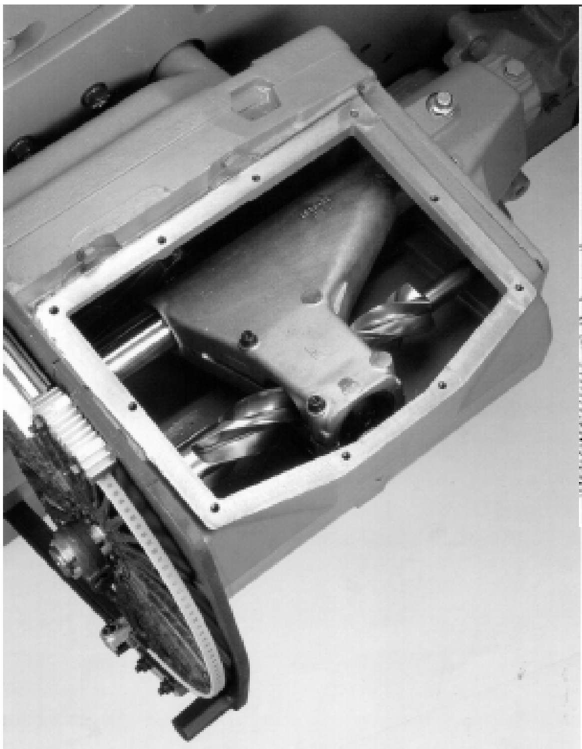


Fig. 40 – Driving system by double conjugated cams

Another system used is the system named ″Propeller″, which is composed of a crank gear combined with a screw/nut screw system which has variable pitch and is designed in such a way as to minimize the accelerations and the vibrations of the rapiers and consequently to reduce the stress on the weft yarn (fig. 41).

In the model with positively controlled clamps proposed by another manufacturer, two complementary disks drive the flexible rapier belts (fig. 42). Two complementary disks in spherical shape 1, fixed on the driving shaft 2, move a lever 3 with two rollers. This lever has also the function of a crank with adjustable eccentricity and, through a bar 4, moves a swinging toothed segment 5, which in its turn works on pinion 6, coupled with the belt driving disk. This driving system permits to select an optimum diagram of movements to deliver the yarn by positively controlled rapiers.



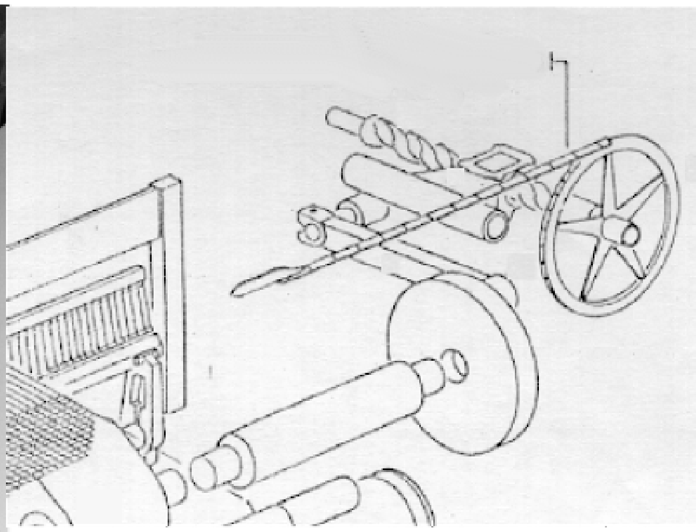


Fig. 41 – Propeller

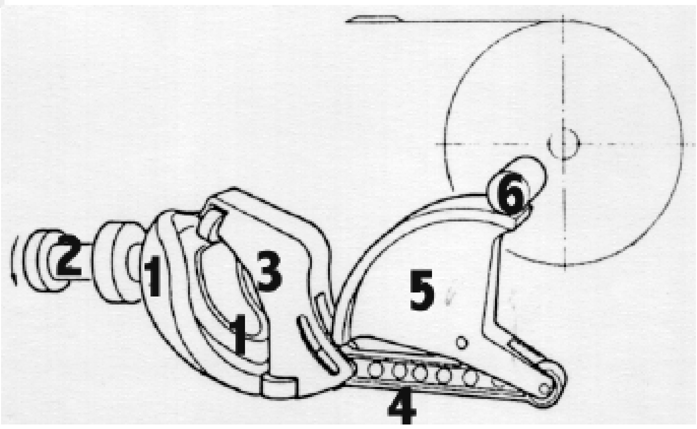


Fig. 42

Finally, another Italian manufacturer uses for the drive of the flexible rapier belts an original system with 3 concurrent axis, which has following operating principle (fig. 43): the main shaft 1, which has a uniform rotating motion, has an oblique spherical cap 2, which generates a swinging movement in a fork 3 and consequently on shaft 4 on which it is mounted. The same shaft 4 carries also a toothed segment 5, whcih meshes with a sprocket 6 and transforms the swinging movement into an alternating rotary motion of the toothed wheel 7 mounted on same axis. The flexible rapier belt, which is mounted on the toothed wheel, converts this movement into an alternating straight motion, as it is forced to move on a straight level.

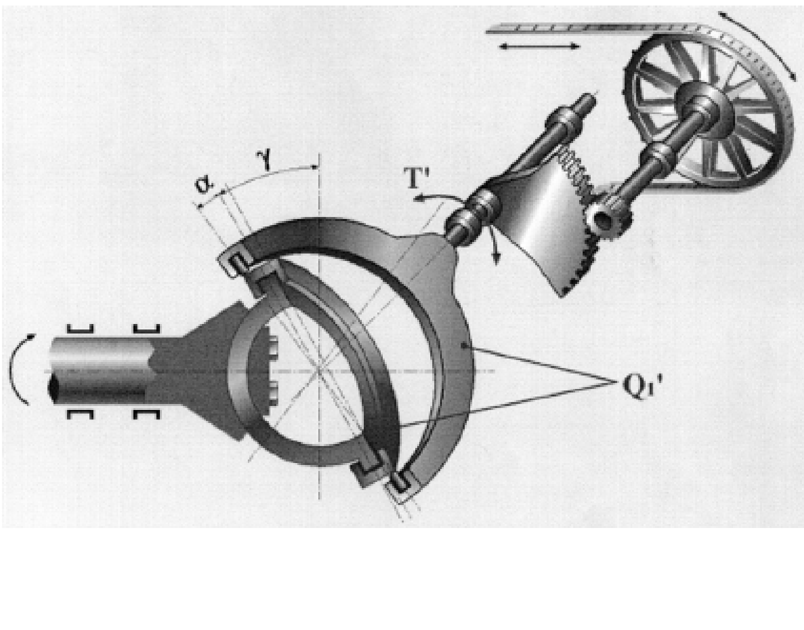


Fig. 43

The colour selector

The colour selector is formed by bolts, which eyes are crossed by the weft yarns. These bolts, which are pushed by proper bolt pushing rods, have the task of presenting each time the selected weft colour. The latest selectors are today available in 3 versions: for 4, 8 and 12 colours. The possibility of inserting up to 12 different weft colours in the same pattern involves that rapier weaving machines are very versatile. This makes them particularly suitable for instance for the tie fabric sector, as they perfectly follow the creativity of the designers.

There are selectors which are built with modular structure in order to increase, whenever necessary, the number of colours; when a new group of machines has to be mounted, it is not necessary to equip immediately all of them with selectors enabling the insertion of the maximum number of weft colours. In fact in case of need every machine can be adapted to the number of weft colours required, by simply changing a single module.

The selectors have rather compact dimensions, so that they form an assembly easily adjustable and quickly movable when changing fabric style.

Most selectors are based on a new technique of stepping motors (the stepping motors are characterized by the fact that they carry out, at each control, a precise angular rotation, called step). These motors, used for all those applications which require rapid and precise positioning, are very efficient and compact and permit very gradual step increases, thus enabling to perfect the weaving sequences.

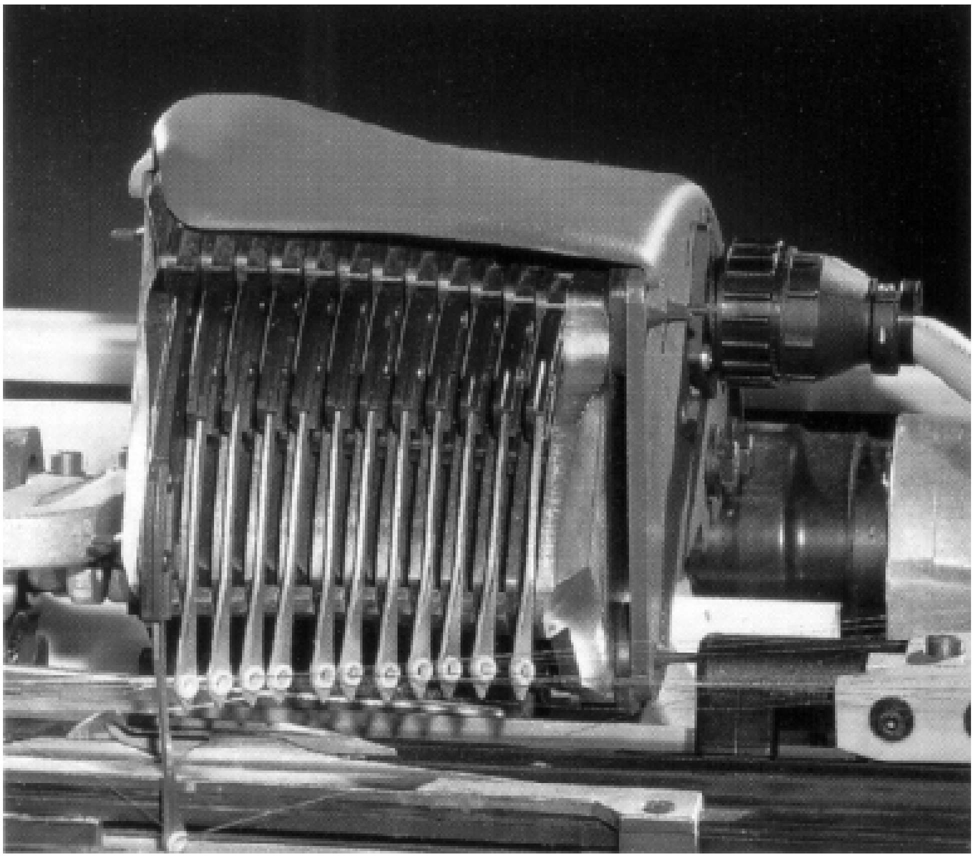


Fig. 44 – Colour selector with 12 bolts

Future objectives

For the future the manufacturers are focussing their attention on following key aspects:

- **versatility:** extending ever more the range of the yarn types suitable for weaving

- **flexibility:** facilitating the switch from a design (style) to another, with unvaried high performance

- **performance:** this is an important aspect which, on occasion of each ITMA, gives the impression of reaching new and insuperable limits; the manufacturers give themselves continuously new targets and make feasible things previously considered as impossible, by virtue of new construction technologies. The rapier weaving machines, having reached a speed of 700 picks per minute, are threatening the market share of air jet weaving machines with dobby. In fact the rapier machine is characterized by an inferior power consumption, by a narrower shed (and therefore by lower dobby speed) and by said versatility.

- **reduction of time needed for style change:** new designs (styles) mean almost always new check-out operations, so that the best solution is not so much the reduction of the time needed for the new adjustments, but rather, if possible, their elimination. In this connection the quick style change (QSC) proved its great usefulness. Also the electronics will contribute more and more to simplify the adjustments and their reproducibility from one machine to the other.

- **further limitation of maintenance costs**

- **noise reduction:** noise is the physical effect of a mechanical vibration diffusing pressure waves in a fluid (air). Noise is therefore generated by any kind of vibrating element. We can locate the cause of the vibrations in the alternating motions which take place in a rapier loom. To reduce the vibrations, it will be therefore necessary to improve the movement of the slay, of the rapiers and of the heald frames, even if a considerable progress has already been attained.

At the same time it will be necessary to minimize the effects of sound waves reflection by developing a suitable design for the machine. Alternatively passive measures are to be taken, by covering the mechanical units with adequately treated casings.

Projectile weaving machines

The projectile weaving machine made its appearance in the market at the beginning of the 50's and is today still used in the whole world. Thanks to its steady renovation and to the use of advanced electronic systems as well as of microprocessors for the supervision and the control of the various devices, this machine is characterized by a good productivity *level **(450 rpm and 1050 m/min of inserted weft)*** and by high operational reliability. It is established especially in the field of machines with high reed width.

General operation

In this weaving machine the weft insertion is carried out by small clamp projectiles (fig. 45), which number depends on the weaving width and which with their grippers take out the weft yarn from big cross-wound bobbins and insert it into the shed always in the same direction.
The projectiles work in sequence, that is they are launched in succession. They run therefore one after the other, describing in the space a continuous, endless route, as if they would be stuck on a conveyor belt.
The first projectile takes and holds in its back the weft in form of a tail; then, pushed by the release of the projectile thrower, it passes through the shed and deposits the weft inside the warp; subsequently the projectile falls and is collected by a device which, by passing under the array of the warp threads, takes it at reduced speed back to the starting point. Here the projectile goes up to take up a new weft; meanwhile the other projectiles have run after each other making the same operation.
Fig. 45 shows the projectile conveyor chain (*shuttle return chain*), the projectile (*shuttle*) with its back clamp to seize the yarn (*thread grippers*), the cutting tool (*scissors*) to separate the inserted weft from the bobbin and the strap which, through twisting, launches the projectiles (*torsion rod*).

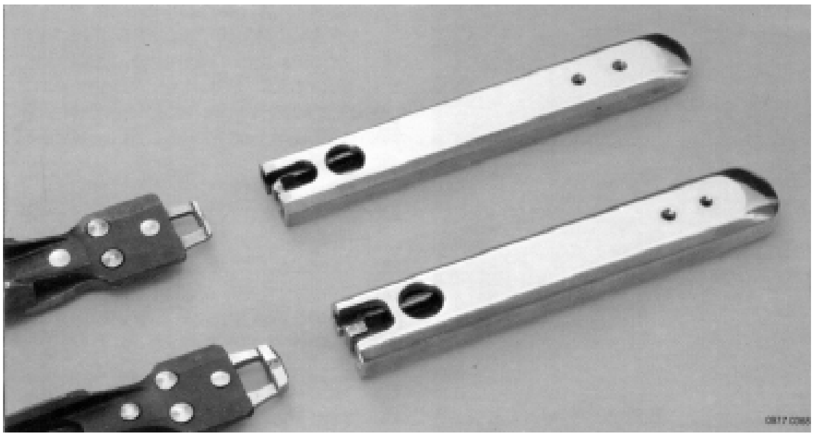


*Fig. 45 – **Projectiles**: there are various projectile versions: made of steel, 9 cm long and 40 g heavy, with small section, as suitable for yarns of fine to medium count; made of steel, 9 cm long and 60 g heavy, with large cross-section which, thanks to their higher weight and to the larger clamping section of the gripper, are particularly suited for machines with high reed width or when for weft bulky yarns, as e.g. fancy yarns, are used.*

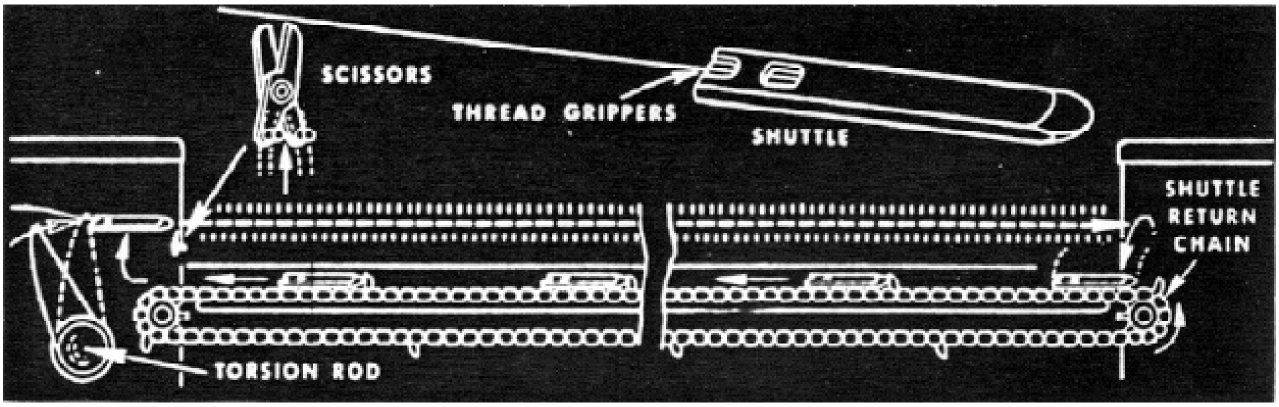


Fig. 46

Projectile guide

The limited weight and the reduced volume of the projectile make a projectile guide necessary (fig. 47). The projectiles therefore do not come into contact with the threads, but run inside a sort of channel composed of the thin prongs of a rake, which form reminds a semi-closed hand. This rake goes up from under the threads at the moment of the projectile launch and has of course to fall back lowering itself at the slay stroke. To enable this movement, the rake is secured on the slay and is positioned very close to the reed; the rake's laminas are not in contact with the warp, or touch it very lightly because the reed opens them the way.
The latest models of the projectile machine have been equipped with new types of guide dents, which are divided and placed in alternate position, in order to reduce the stress on weft and warp threads. This permits to use in warp even very delicate yarns as for instance untwisted or entangled yarns and at the same time to cope with high quality requirements.

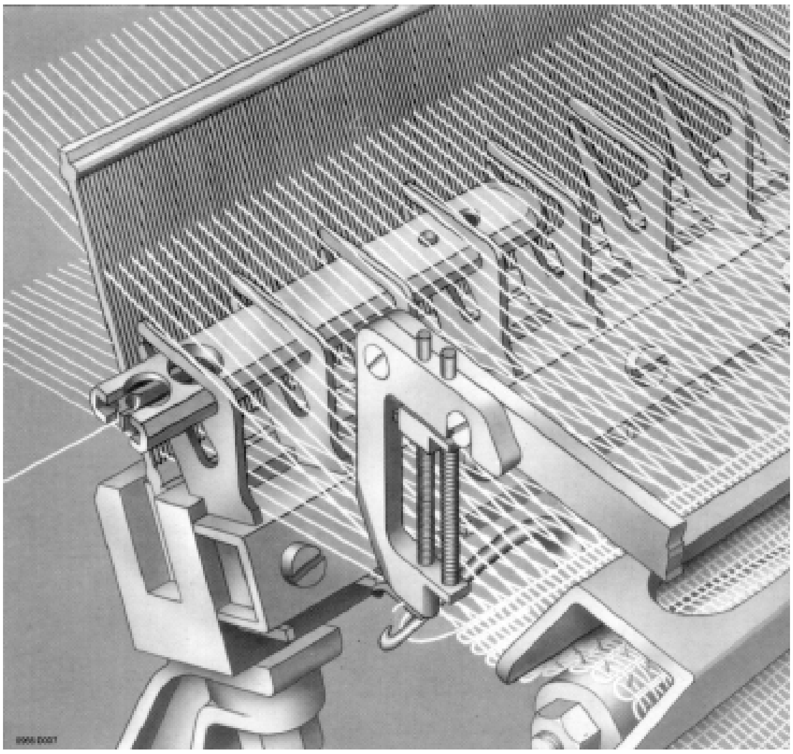


Fig. 47

Projectile launching mechanism

The operational principle of the launching mechanism is the following (fig. 48 and 49): a torsion bar 2 is anchored, at one side, to the fixed point 1, whereas the free end is connected by a toothed groove to the percussion shaft 3. The percussion lever 9, which is fixed to the percussion shaft 3, follows per force the movements of this last and consequently of the free end of the torsion bar 2. During its rotation, the cam 8 shifts the knee-joint lever 4+5, so that the torsion bar 2 is put under tension by the percussion shaft 3 and the percussion lever 9 is put in launching position (the scheme shows the launching mechanism with the torsion bar in the phase of maximum tension). The torsion bar 2 remains under tension until the roller 7 slides along the bend of lever 5. The particular shape of this lever makes so

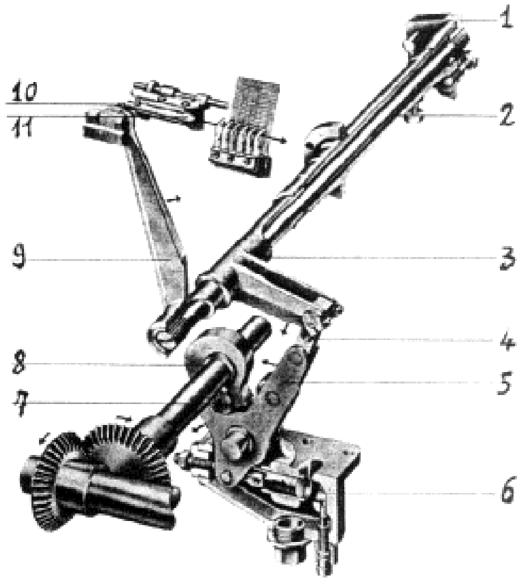


Fig. 48 - Projectile launching mechanism

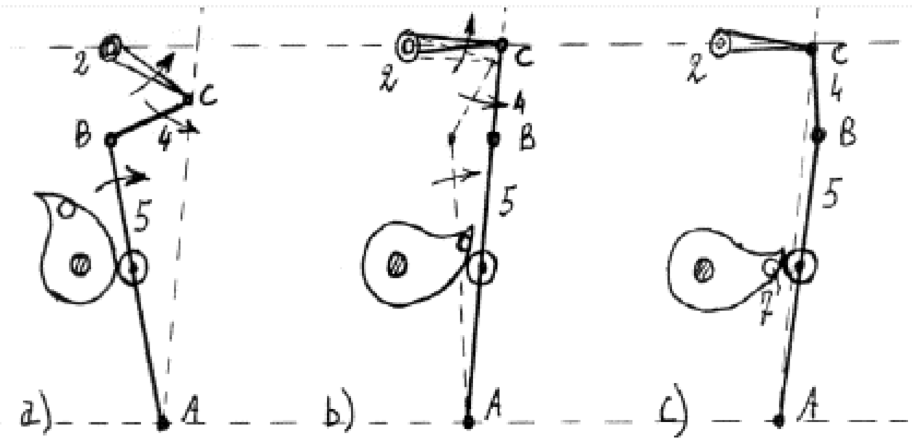


Fig. 49 – Loading of the torsion bar: a) torsion bar 2 in rest, knee-joint lever 4+5 in articulate position; b) loading phase; c) torsion bar in tension and knie-joint lever in stable position, before the launching control by roller 7.

that the roller, when leaving it, presses its end, thus giving the starting point to the torsion bar for the articulation of the knee-joint lever 4+5. Subsequently the torsion bar 2 returns suddenly to its rest position imparting a strong acceleration to the projectile 11 through the percussion shaft 3 , the percussion lever 9 and the percussion element 10. The oil brake 6 serves to damp the stroke.
The projectile's stroke time, that is the insertion time, is adjusted by modifying the torsion angle of the bar through an angular shift of the anchorage point, which has proper adjustment windows.

Insertion cycle of the projectile machine

The schemes in Fig. 50 show the insertion cycle of the projectile machine:

a) The projectile 1 is put in launching position; the weft is hold at its end by the weft carrier 2 and is controlled by the weft tensioner 3, by the weft brake 4 and by the eyelet 7 situated in proximity of the feeding bobbin 8;

b) The weft carrier 2 gets open after the projectile clamp has got hold of the end of the weft thread;

c) The projectile 1 is launched and crosses the shed dragging with itself the weft, while the weft tensioner 3 and the weft brake 4 operate in a way as to minimize the stress on the yarn (the critical phases are particularly the initial acceleration phase and the final stop phase in the collector box);

d) The projectile 1 on the one hand and the weft carrier 2 on the other take up the right position to build up the selvedge, while the tensioner arm opens to adjust the weft tension;

e) The weft carrier 2 closes while the selvedge clamps 5 get hold of the weft thread on both sides and the projectile clamp is opened to release the weft end;

f) The thread is cut by the scissors 6 on the launching side, while the projectile 1 is placed in the transport chain;

g) The weft is beaten by the reed, while the weft carrier 2 moves back to its initial position and the weft tensioner 3 opens further to recover the thread piece and to keep it under tension. The projectile is brought back to the launching zone;

h) The selvedge needles 9 insert the weft ends into the subsequent shed (tuck-in selvedge), while a new projectile is placed in launching position.

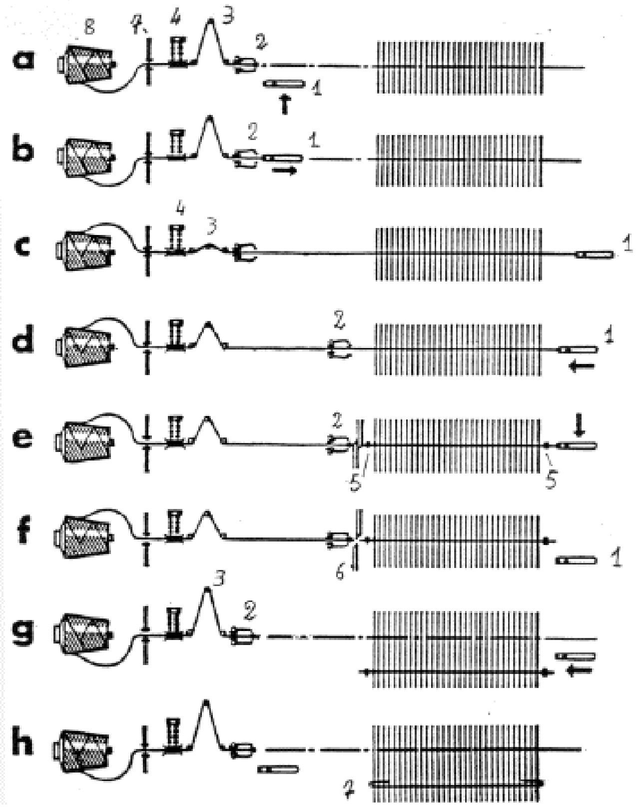
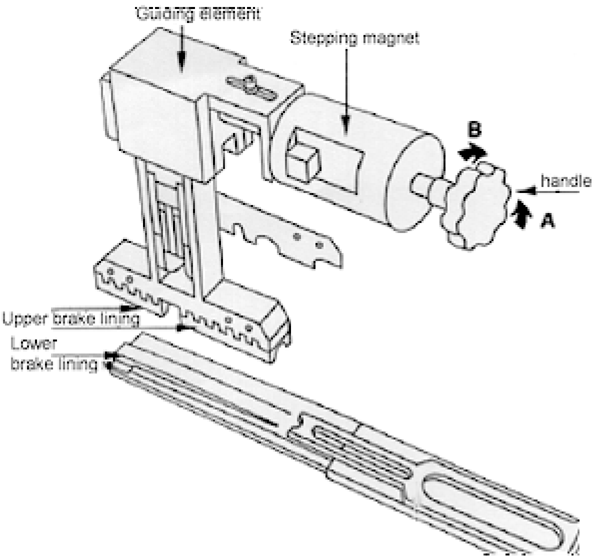


Fig. 50 – Insertion cycle of the projectile machine

Electronically controlled projectile brake

The present machines have the projectile brake adjusted by a microprocessor, and this permitted to increase the efficiency rate and to reduce the maintenance costs.
The electronically controlled brake has the function of stopping the projectiles in the correct position, without any need of manual intervention (contrarily to previous mechanism).
This result is obtained by means of a controlled double upper brake lining and of a lower fixed brake lining (Fig. 51 and 52). The mechanism works as follows: the sensor 1 and 3 detect the position of projectile 4 inside the collector mechanism and communicates it to a microprocessor which, on the basis of the received information, transmits a corresponding order to the stepping magnet 14. This last operates on a wedge-shaped guide element 13 which, by shifting the upper bracket lining 8, modifies the braking intensity. The sensor 2 controls instead the timely arrival of the projectiles in the collector mechanism.
Three cases are possible:

A) Position I (normal projectile position): the control co-ordinates S of sensors 1 and 3 are covered by the projectile;
B) Position II (projectile too far penetrated / insufficient braking): the control co-ordinate S of sensor III is not covered;
C) Position III (projectile insufficiently penetrated / excessive braking): the control coordinate S of sensor 3 is not covered.
In the first case the microprocessor does not answer; in the second and third case, it causes respectively the closing and opening of the brake, thus controlling the number of steps necessary to bring the projectile again to normal position.



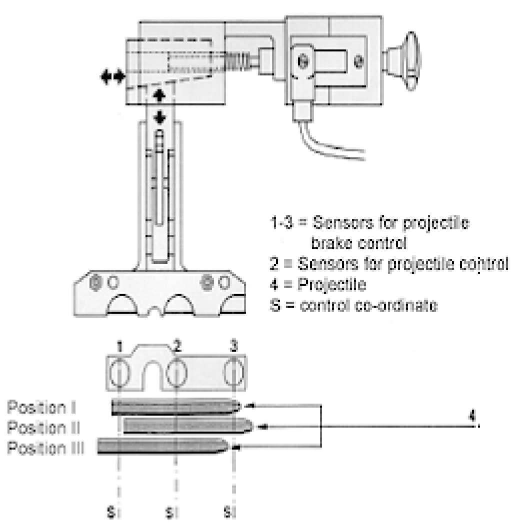


Fig. 51 – Projectile brake

Fig. 52 – Brake adjustment

Colour selector

In the multi-colour weaving machine, the weft carrier is controlled by a turret loader (fig. 53); as it is a 4-colour system, 4 weft carriers will be mounted on the loader. The weft carrier loader is driven by a conical gear controlled by a toothed quadrant; when the quadrant moves upwards or downwards, the loader is pushed in the opposite direction and the extension of the oscillation defines which carrier to take position opposite the clamp of the projectile to be launched. A block ensures that the turret loader remains in the selected position until further order. In the case of cam-controlled heald frames, the colour is selected by a punched card special unit.
If the heald frames are driven by a dobby or by a Jacquard machine, the gear which drives the toothed quadrant is integrated in the dobby or in the Jacquard machine.
The modern selectors are controlled by servomotors and the weft sequence is programmable.

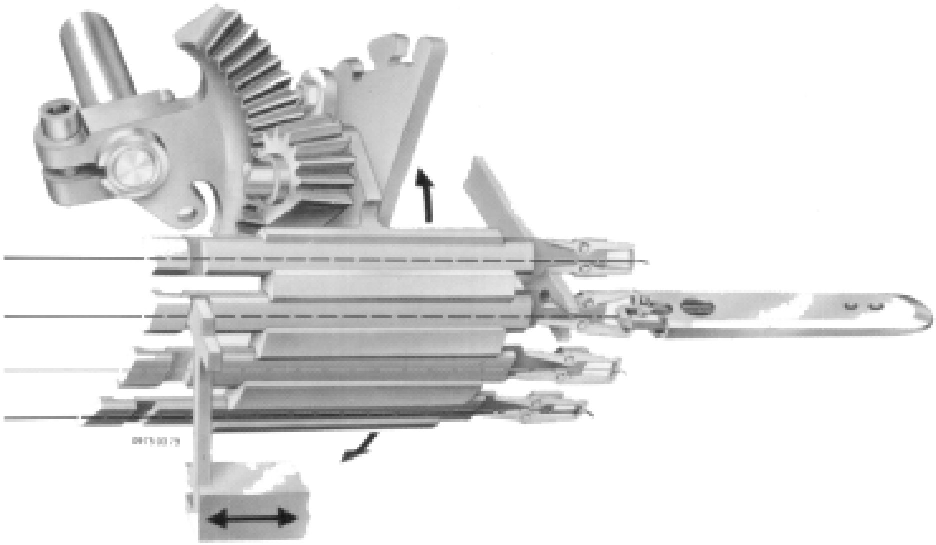


Fig. 53 – Colour selector

Air jet weaving machines

The air jet weaving machines are the weaving machines with the highest weft insertion performance and *are considered as the most productive in the manufacturing of light to medium weight fabrics, preferably made of cotton and certain man-made fibres* (sheets, shirting fabrics, linings, taffetas and satins in staple yarns of man-made fibres); it has anyway to be pointed out that technically positive results are obtained at present also with heavy weight fabrics (denims) and that some manufacturers produce also machine models for terry production. These machines are the ideal solution for those who want to produce bulk quantities of customized fabric styles.

The weaving widths range generally from 190 to 400 cm. As regards the multicolour weft carrier, up to 8 different wefts can be fed.

It has however to be considered that the air jet weaving machines require a high energy consumption to prepare the compressed air and that this consumption rises definitely with increasing loom width and running speed. The reduction in the energy consumption is in fact one of the main concerns of the manufacturers, and builds for the user an important selection criterion.

General operation

The operation principle is the following: the thread, prepared in a given length (corresponding to the reed width) by pre-measuring weft carriers (fig. 54), is launched through the shed by a jet of compressed air.

The typology of the weft inserting medium (no mass in motion) permits high weft insertion rates (on an average 2000-2500 meters/min and 1000 strokes/min).

The air jet weaving machines require air ducts capable of maintaining an effective air flow on the whole weaving width. To obtain this, the machine manufacturers prefer today to use the system with profiled reed, in which the air and the thread are guided through a tunnel-shaped reed (fig. 55).

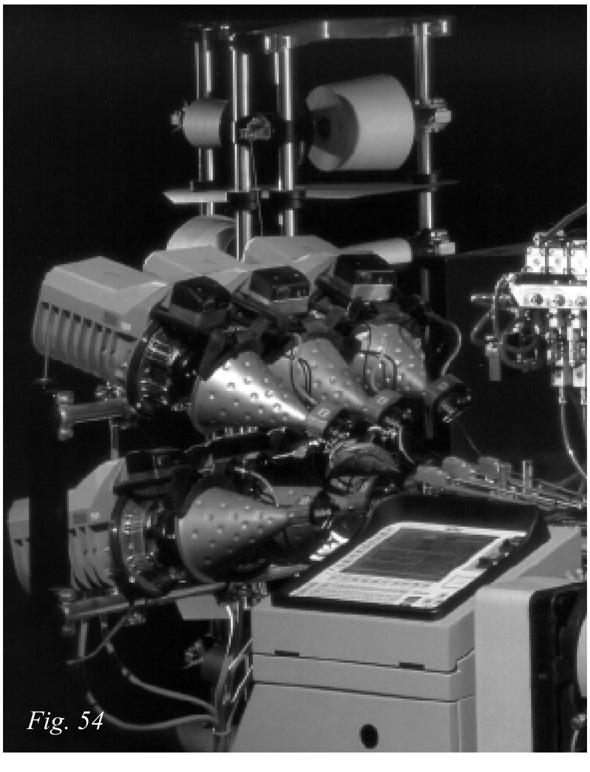


Fig. 54

Fig. 55

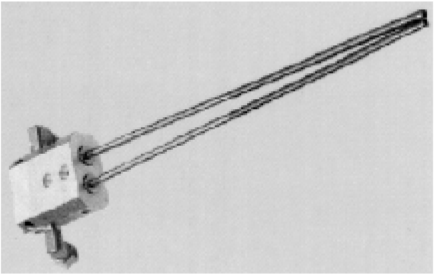


Fig. 56 – Main nozzles

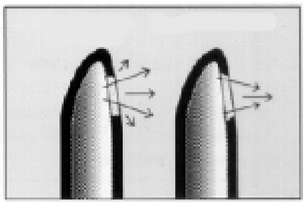


Fig. 57 – Multihole relay nozzles

The weft is placed in the groove formed by the reed's profiled dents, in which it remains until the reed stroke.
In the air jet weaving machines, the impulse causing weft launch is provided by a main nozzle (fig. 56), but the jet of compressed air, being blown in a room of same kind, looses very quickly its own energy. Consequently, if the weft has to be transported along reasonable widths, the use of additional gears, that is of secondary or auxiliary (or relay) nozzles is necessary; these, besides pushing the weft forward, have also the task of keeping it inside the guide channel.
The auxiliary nozzles are stationed along the whole reed width and operate according to the relay principle (fig. 58); the nozzle holder blocks are connected groupwise to the distributors of compressed air by means of flexible pipes. The multi-hole relay nozzles (fig. 57) applied on modern air jet weaving machines accelerate the weft motion in the best way, at the same time reducing the stress on the yarn and helping towrds increasing machine yield and performance.
The manufacturers are increasingly installing on the weft delivery side of the shed a suction nozzle which has the function of maintaining stretched the weft pending the stroke of the slay and the consequent weft binding in the fabric. This ensures a perfect stretching of the weft inside the shed with any kind of yarn, even with the most critical yarns.
Among the various optional devices offered by some manufacturers, we point out in particular the auxiliary main nozzle; the combination of an auxiliary main nozzle with the main nozzle accelerates the weft motion but under low pressure, thus avoiding damaging the yarn.
A particular characteristic of the last models of weaving machines is the automation and the supervision of the machine with the aid of microprocessors. An automatic regulation system (fig. 58) optimizes the air pressure in the machine, adjusting it to the variations of yarn

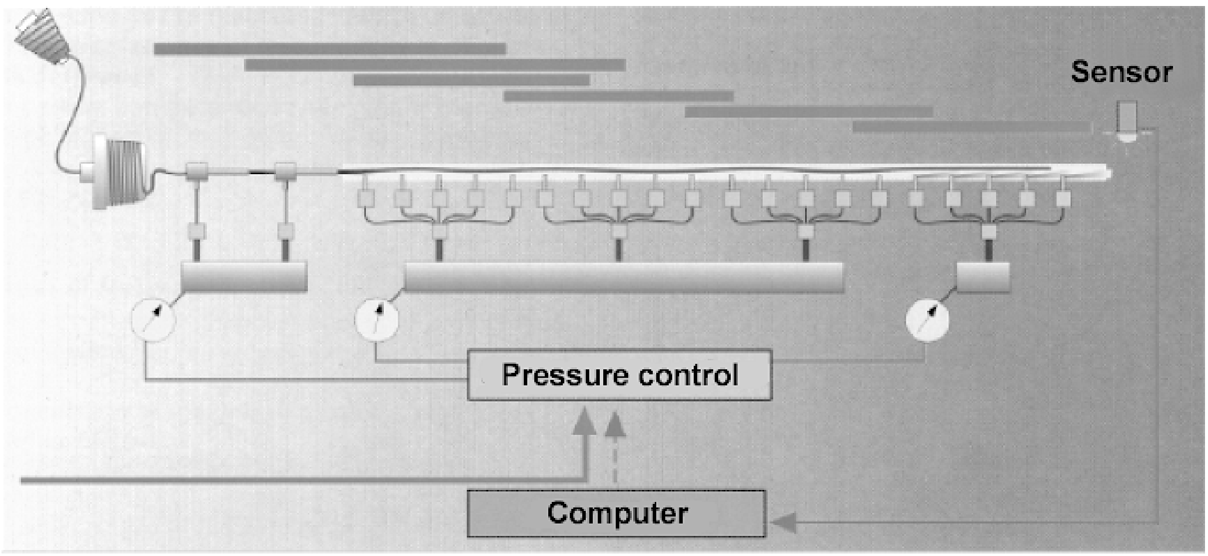


Fig. 58

characteristics. Thanks to this system, the pressure of the main nozzles and of the relay nozzles is self-adjusting depending on the yarn structure and on the resistance opposed by the yarn to its unwinding from the bobbin, which resistance varies with the changing of the balloon shape during the progressive emptying of the bobbin. This self-adjustment of the launch parameter takes place on basis of the weft arrival time, which is detected by the sensor of the weft stop motion. The weft arrival time needs to be constant in order to get always the same tension in the yarn; otherwise the yarn gives up its ideal way of operating, causing defects in the fabric and a higher number of machine stops. This way, besides avoiding machine stops and unnecessary adjustments, the consumption of compressed air is reduced to a minimum.
The warp let-off, the pick finding device or the levelling-off device of the heald frames to avoid defects on the fabric when restarting the loom, are anyway electronically controlled. Electronic and computer controlled systems are used also for weft colour selection and to prevent formation of starting marks.

Automatic weft repair

An important characteristic of these weaving machines is also the automatic repair of weft breakages, which on some loom models is standard equipment, while on other models is optional. We stress the fact that air jet weaving machines are the only weaving machines which permit to repair reliably most weft defects. The automatic weft repair contributes to reduce the global down time of the machine (the automatic repair device is always ready on place, contrarily to what happens with the weaver) and improves the quality of the product. At the same time it permits to increase the number of machines allocated to the single weaver, and consequently to reduce labour costs.
The scheme of Fig. 59 illustrates the sequence of the automatic weft repair proposed by an Italian manufacturer.

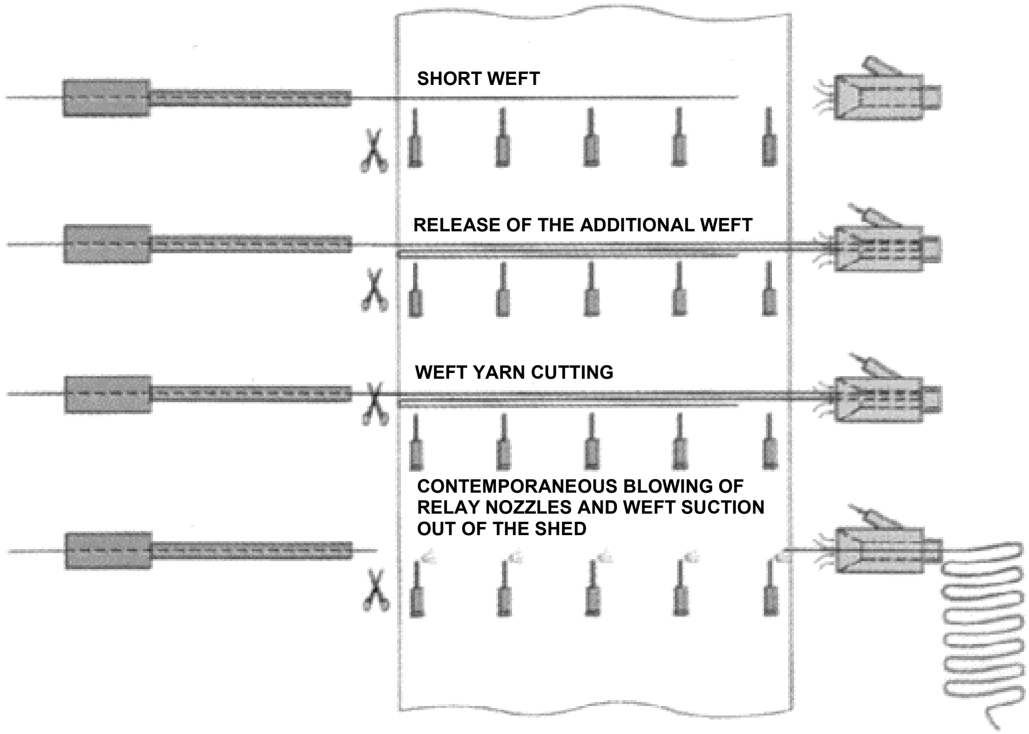


Fig. 59 – Automatic weft repair

The scheme shows how the faulty short weft is released from the fabric while a new additional weft is inserted (and the thread trimmer is temporarily disconnected); later the additional weft is cut and the relay nozzles in combination with the suction nozzle throw out the additional weft and the short weft.

Conclusions

To sum up, we can say that the production flexibility of the air jet weaving machines has been definitely improved thanks to the possibility of weaving an increasingly wide range of yarns (spun yarns, glass fibre yarns, continuous filament yarns) and of using Jacquard machines for the shed formation, as today by most machine models.
Air jet weaving machines are the easiest to be automated, as all main mechanical functions are controlled by a microprocessor. This last controls and stores efficiently the production data and provides a bi-directional communication between the machines and the main production computer. This way also the transfer of operational data, designs and adjustments can be performed on-line besides by
memory card.
Finally we wish to stress the present trend of the manufacturers to develop their air jet weaving machines on the basis of their own rapier loom. This way the two machines have in common about 65% of the electronic elements, most of the accessories and make use of the same user interface. The servicing and maintenance personnel works on machines which, apart from the different insertion systems, present a unitary structure. The possibility of exchanging the accessories and the quasi identity of the spare parts permits to save money and to reduce storage. By using both loom types (of same manufacturer), the weaver creates in the weaving room a natural integration to the advantage of versatility, productivity and quality.

Water jet weaving machines

These machines are produced only by few companies and are used for the manufacture of light and medium weight fabrics with standard characteristics and in water repellent fibre materials, primarily multi-filament synthetic yarns. Water jet machines are extensively used in East Asia, but have limited importance in other countries. They are characterized in particular by high insertion performance and low energy consumption.

Operation principle

Fig. 60 shows how the machine operates. The weft yarn, which is fed from cone 7, is drawn-off by a feeding and measuring device 2 and then passes through a tension regulator 3 and a weft clamp 4. When the insertion has to take place, the weft clamp loosens its hold and the thread inserted inside a nozzle 1 is struck by a jet of pressurized water and launched through the shed at high speed. After the insertion has taken place, while the weft is hold flat by the threads which are moved by the leno mechanisms 5, the thermal knives 14 enter into action on the launch side to cut the weft, and on the opposite side to trim the fabric. A yarn clamping device 13 holds the weft waste which is cut off by the right-handed thermal knife, while rotating gears arrange for its removal (centre selvedge).
The water is conveyed by a pump 8, provided with a filter, the piston of which is controlled by a cam 10 producing the phases of water suction from the container 9 and of water supply to nozzle 1.

The sequence of the launch phases is the following: the pump 8 enters into action and the initial water jet serves only to straighten the residual small piece of weft, from nozzle 1 to thermal knife 14. This action, which has a duration time varying from 5 to 30 rotation degrees of the main shaft, depends on the yarn count and is named guide angle. The yarn flight forms a so-called flight angle, leaving clamp 4 open to permit to the pressurized water jet to insert the weft thread into the shed. The clamp opening time varies according to reed width and to loom running speed. On yarn exit from the shed, there is an electrical feeler or an infrared sensor which checks the presence of the weft end and makes the machine to stop in case of absence of the weft.

A drying device removes the humidity absorbed by the fabric, sucking it through grooves produced in the front beam 6 of the machine. A maximum of two weft colours can be inserted (weft mixer).

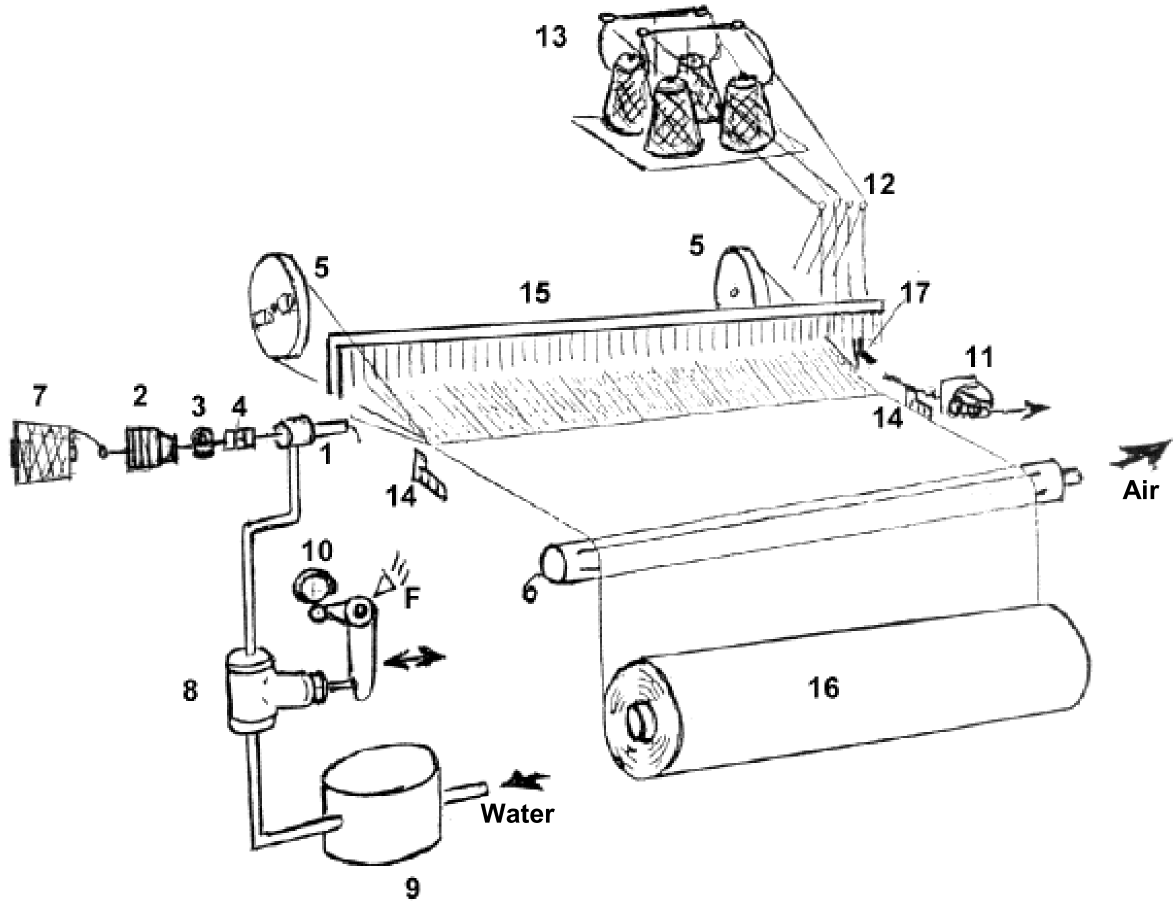


Fig. 60 – Scheme of a water jet weaving machine

As to the weaving width, they are around 2 meters.
The devices used for shed formation are either pedal eccentrics (cranks) or cams or dobbies; Jacquard machines are not used, because water jet machines are suitable for mass production of plain fabrics.
We conclude reminding that water jet machines, though having high performance and low operational cost, are interesting only for the textile producers of certain sectors which are in Europe less developed then in the Far East.

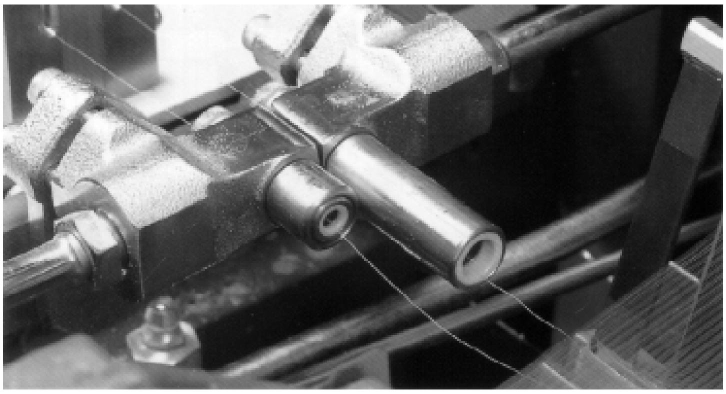


Fig. 61 – Insertion nozzles for 2 different threads

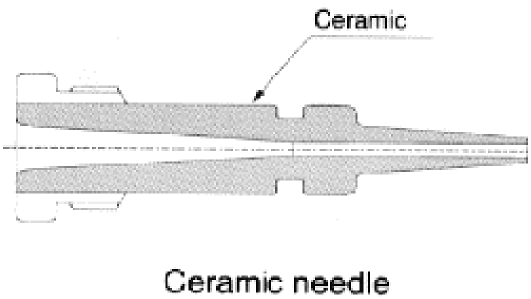


Fig. 62 – Cross–section of a ceramic nozzle

Special weaving machines

This definition identifies the weaving machines equipped with particular devices to permit the production of particular types of fabrics. We shall handle here terry fabrics, double velvets and narrow fabrics weaving machines.

Terry weaving machines

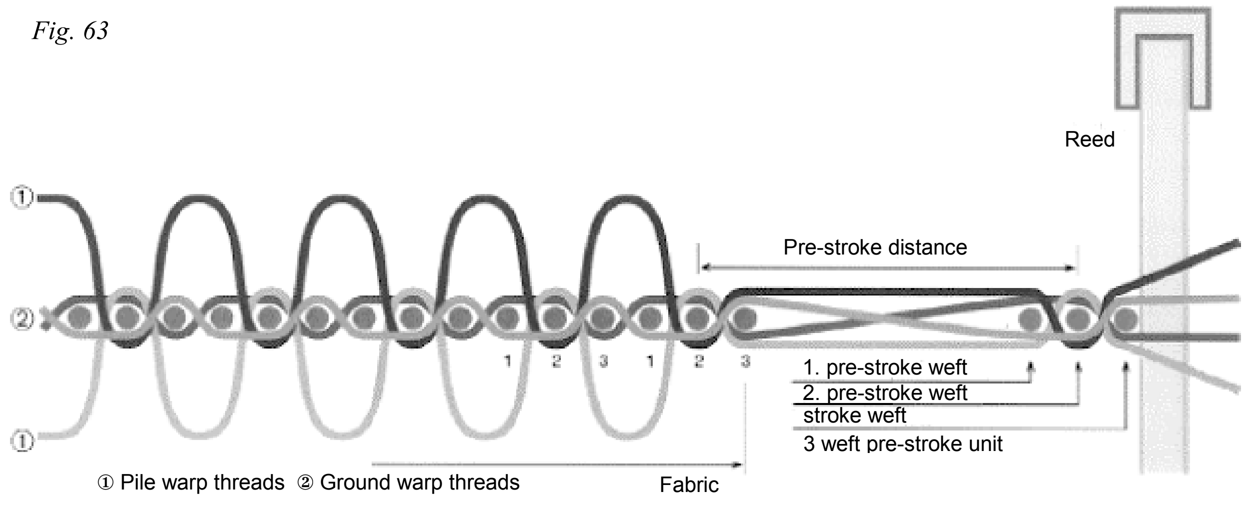
For the production of terry fabrics, following machines are used: rapier, projectile or even air jet machines. These machines differ from the standard machines for plain fabric production owing to following features:

1. double bearing, to house two beams: the ground warp beam, generally situated down, and the loop yarn beam, in upper position in order not to increas floor space requirement, even when using large diameter beams;
2. double warp let-off electronic motions with auxiliary motors electrically connected to the driving motor of the cloth take-up roller and controlled by the machine's PLC;
3. loop formation mechanism: this device permits to close up the wefts to the cloth formation edge during the first two or three insertions, however without tightening them completely (short stroke or pre-strokes), and to produce their definite tightening against the cloth together with the third or fourth weft (long or loop stroke), with subsequent formation of the loop by the effect warp. This occurs because the group of wefts slides on the stretched ground threads, while the less tensioned threads of the pile warp, being tied up within the group of wefts, bend to form loops. The distance

of the wefts closed up to the cloth formation edge (pre-stroke length) gives rise to the loop height. This last can present maximum values ranging, depending on the manufacturer, from 19 to 25 mm, corresponding to maximum loop height between 9 and 12.5 mm;
4. electronic microprocessor controlled device: this permits to program the formation of the various effects (high loop, low loop, absence of loop, fringes) by means of an automatic control of the related mechanisms. Moreover it permits to program the manufacture of single towels or of towel sets in a prearranged number, and to execute on each of them a sequence of motifs. The sequence can be programmed at will, according to one's own needs, or can be chosen out of a series of programmed sequences.

The loop forming mechanisms mostly in use are based on the principle of causing a shifting of the fabric and of the warp, so as to modify the position between the stroking reed and the fabric formation edge.
The reed maintains a regular movement, whereas the fabric edge is displaced periodically from the stroke point through the horizontal shogging of the temples, of the cloth diverting beam and of the back rest roller. Thus two or three pre-strokes followed by a loop stroke are produced, with the consequent formation of the loops.
Fig. 63 shows the cross-section through the warp of a double terry (loops on both sides) with loop repeat every 3 wefts (two pre-strokes and one loop stroke). The ground weave is an irregular warp rib (2/1), an ideal weave to attain a good anchorage of the pile threads.
Fig. 64 shows a general view of a teddy weaving machine, while Fig. 65 illustrates schematically the loop formation mechanism. The cam 1 which is mounted on a tertiary or quaternary shaft causes – with its maximum diameter, through the roll lever 2, the pull hook 3, the lever with regulation window for the high loop 5 and the lever 6 with fulcrum on the summit – the shift of rail 7, which moves the fabric formation edge away from the stroke line during the insertion of 2 or 3 wefts, depending on the loop repeat. This way the reed can only close up the wefts (pre–strokes) to the fabric and their distance from the fabric gives rise to the loop height. The temple 8 follows the movements of the fabric, being mounted on a lever with a pendular movement.

Fig. 63



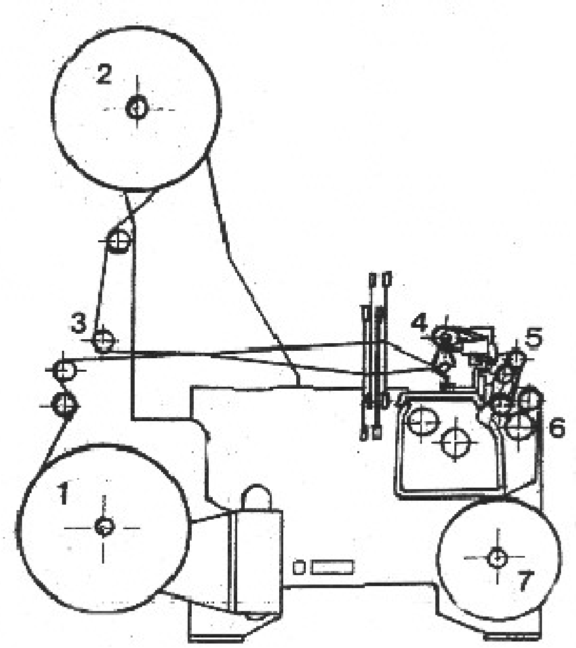


*Fig. 64 – **Terry weaving machine**:*
1. Ground warp beam
2. Loop warp beam
3. Swinging back rest roller for tension compensation
4–5–6 Loop forming device
7. Weaver's beam

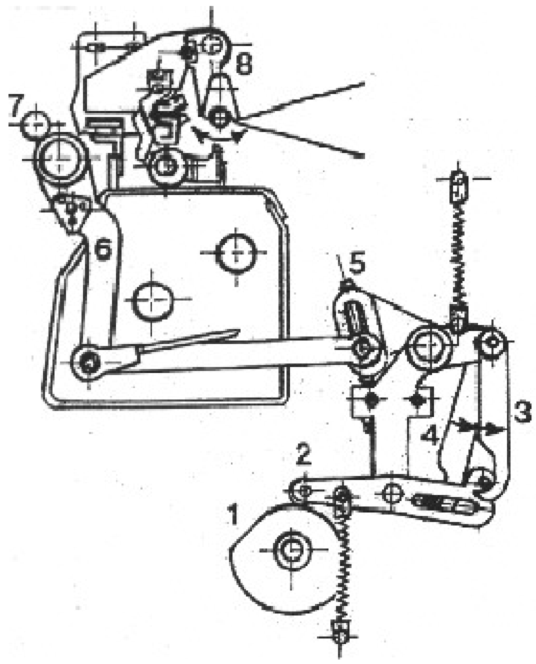


*Fig. 65 – **Terry weaving machine**:*
fabric motion gear

On the contrary, when the cam presents the minimum eccentricity, the fabric is taken-up by springs and can return to its normal position so that the subsequent stroke, through the contemporary tightening of the group of wefts, forms the loop. There is also the possibility, by excluding hook 3 and inserting hook 4 as the driving element, to produce a second loop height (low loop), which is lower than the normal height, by adjusting the position of the linking slider of hook 4, in the window of lever 2, according to a programmable sequence. Through the exclusion of both ratchet gears, the machine produces a loop free fabric.

A second type of gear for loop formation uses, to perform short strokes or pre-strokes, a device which reduces the reed stroke, while the fabric remains always in its normal position. As an example we present a mechanism of latest design, which offers new and wider possibilities of forming the loop as compared with traditional methods.
Fig. 66 provides a general view of the machine with the loop forming devices. We wish to draw the attention to the stepping motor M which is controlled by a microprocessor and permits to program in a frequency at choice, several pre-stroke distances (until 200) on values up to a maximum of 20 mm adjustable in steps of ± 0,1 mm each, thus obtaining corresponding pile heights, up to maximum 10 mm.
Moreover it is possible to produce fabrics with different, alternating loop repeats (for instance on 3 or 4 wefts). By using a suitable weave, it is also possible to obtain terry fabrics with loop repeats on 5, 6 or 7 wefts, which permit to produce at the same time two different loop heights in weft direction. The cross sections in Fig. 67 are an example of this technical possibility.

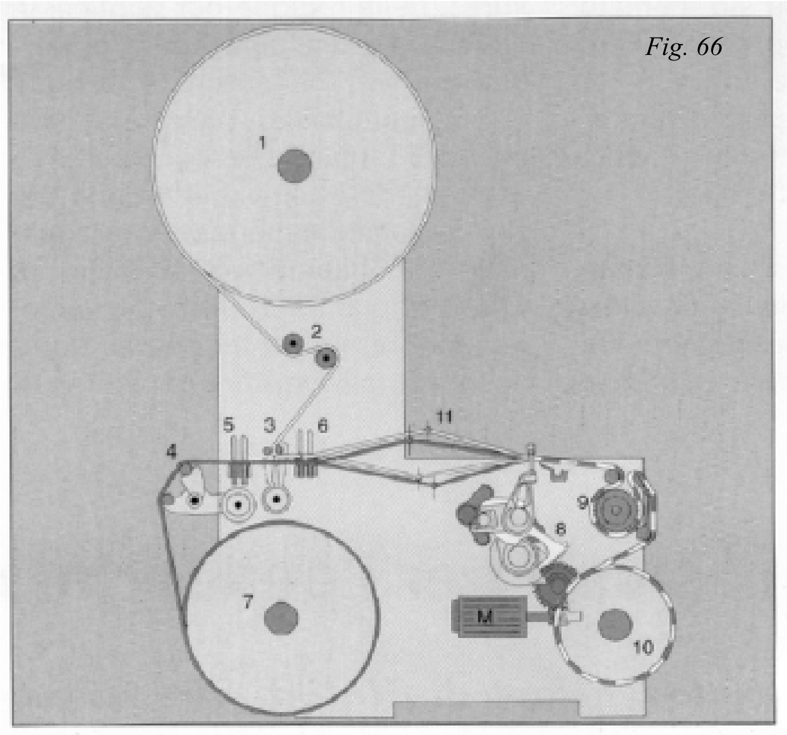


Fig. 66

1 Beam of pile warp
2 Deflecting rollers
3 Pile warp back rest roller
4 Ground warp back rest roller
5 Ground warp stop motion
6 Pile warp stop motion
7 Ground warp beam
8 Drive for the reduction of the slay stroke
9 Fabric unwinding
10 Weaver’s beam
11 Shed formation through Jacquard, dobby or cam motion

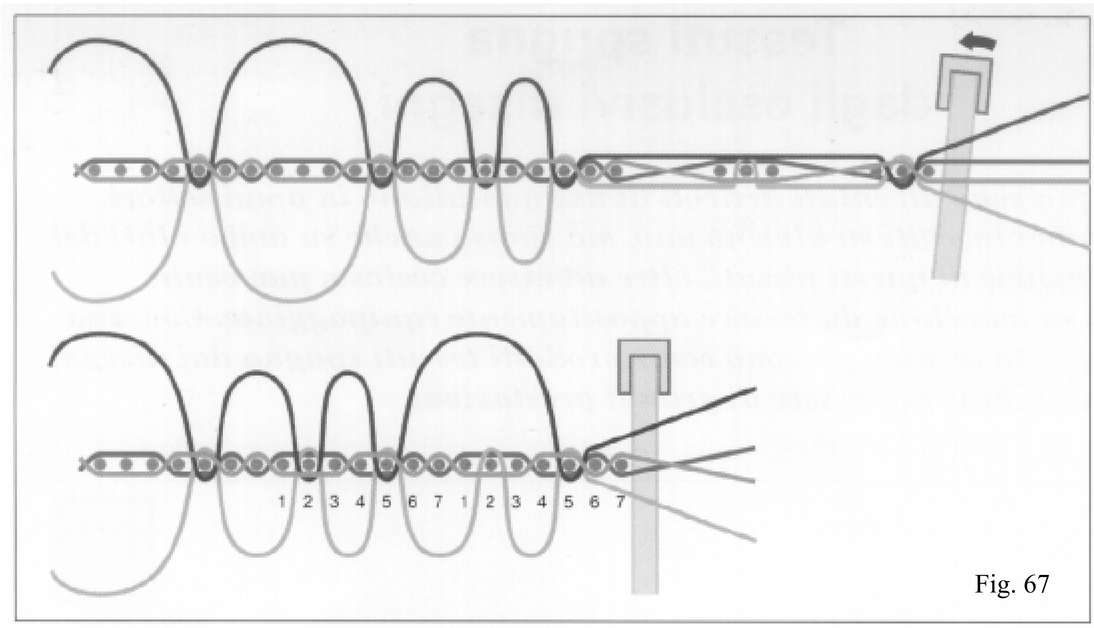


Fig. 67

Fig. 68 shows the mechanism used to reduce the reed stroke (short stroke or pre-stoke). Through a helical wheel 1 and the toothed quadrants 2, 3 and 4, the microprocessor controlled stepping motor modifies the profile of cam 5 and consequently the position of the roller cam follower 6. This last imparts a rotation to shaft 7 which on its turn, owing to its anchorage to lever 8 fixed on reed support shaft 9, forces also this last to carry out a rotation (anti-clockwise as in figure), which causes a reduction in the reed stroke. This occurs because the cam follower 10, driven by the complementary profile cam 11 which controls the reed, operates on shaft 9 not directly, but indirectly through shaft 7 and lever 8. The rotation of the stepping motor in the opposite direction reinstates the normal reed position and permits the loop formation stroke.

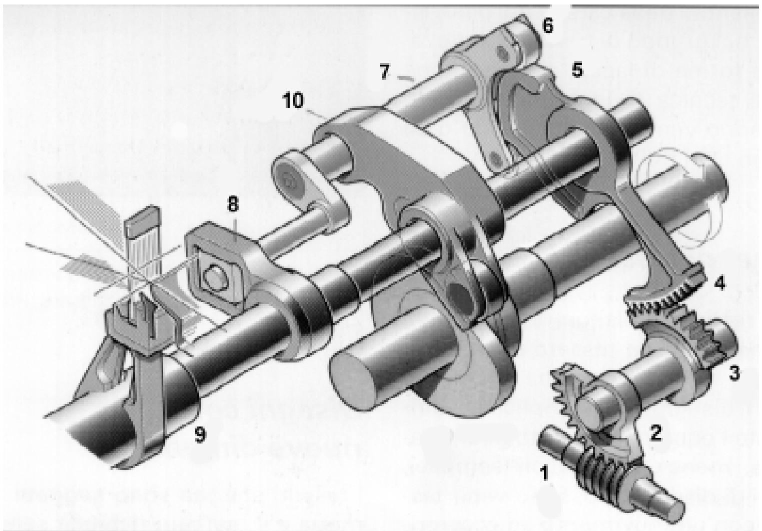


Fig. 68

Double velvet weaving machines

While loop pile velvets are produced with wire weaving technique, which is quite labour intensive**,** cut pile velvets are produced on particular machines which permit to obtain two pieces of fabric at the same time.

These machines are equipped with a 3 position shedding device (dobby or Jacquard machine), so as to form two overlapped and properly spaced out sheds and to permit to the pile warp to tie up the two fabrics together. Into each of the two shed a weft is inserted, usually by means of a pair of superimposed rods driven by the same gear (Fig. 69).

The pile warp is subsequently cut directly on the machine through a blade with horizontal traverse motion, thus forming the pile on both fabrics, which are then wound up separately. This system is largely used today owing to its high performance.

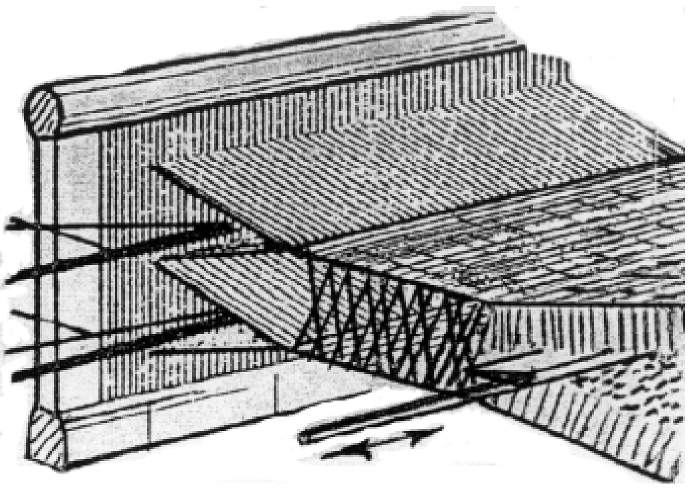


Fig. 69 – Double velvet weaving machines

Ribbon weaving machines

The name ribbons identifies fabrics usually with a minimum width between 5 and 20 mm. They are produced today on particular multi-head machines with 2 to 12 heads, which are interchangeable at will and thus permit weaving several ribbons at the same time. The warp threads can be fed by beams or by a bobbin creel. The shed is formed by frames driven by cams (in case of small weft repeats) or by disks bearing linear cams composed of of glieder chains (these are small cams linked together to form closed rings) in case of larger weft repeats. When weaving figured ribbons, the threads are controlled by an electronic Jacquard machine. The weft is inserted into the shed by a particular mechanism (Fig. 70). The thread taken up from bobbin 1 passes through a weft feeder which adjusts its quantity and tension, then enters the eyelet of a weft inserting element 2 composed of a bent traveling arm which, while penetrating into the shed 3, drags the weft until it protrudes properly from the opposite shed side 4, where a driven latch needle holds it when the weft feeder returns to its starting position; this way a double weft is laid down in every shed.

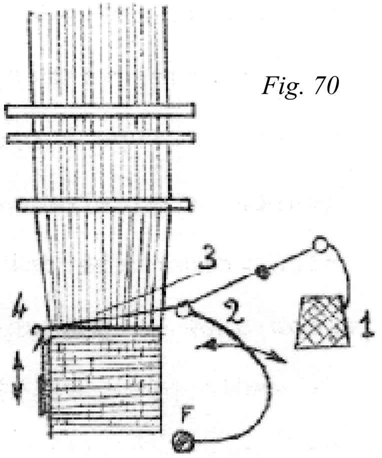


Fig. 70

The latch needle will form with the subsequent wefts a mesh chain originating the selvedge. In order to get a firmer selvedge, an additional resistant yarn (supporting yarn) can be knitted separately or together with the wefts. Fig. 71 shows the different binding systems. On the other fabric side the selvedge is formed in the normal way by interlacing the warp threads.

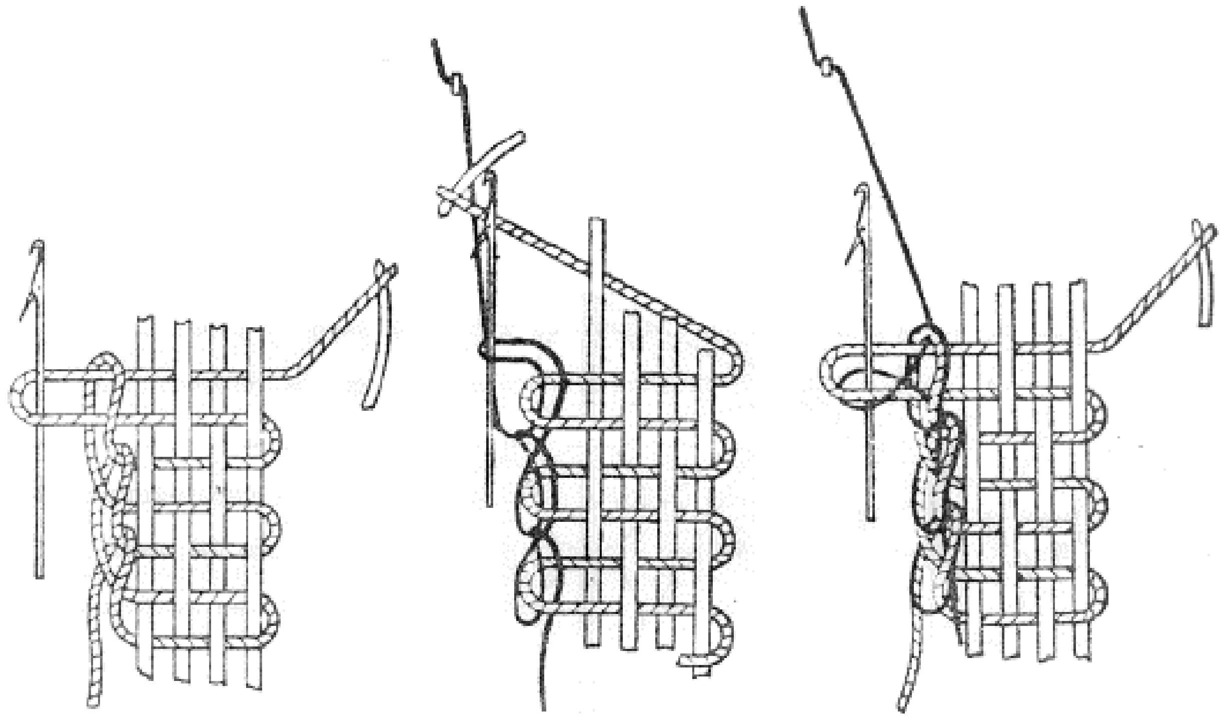


Fig. 71

Fig. 72 shows a driving mechanism for the weft feeder (sickle).
The shaft 1 transmits through the bevel gear pair 2 a rotary movement to crank 3 and rod 4, which transform it into the rocking motion of the toothed quadrant 5 and of the gear 6 connected with the feeding sickle 7, which this way carries out an alternate, curvilinear motion and inserts the weft presented by thread guide 8 into the shed.
Fig. 73 shows a modern 8 head needle loom.

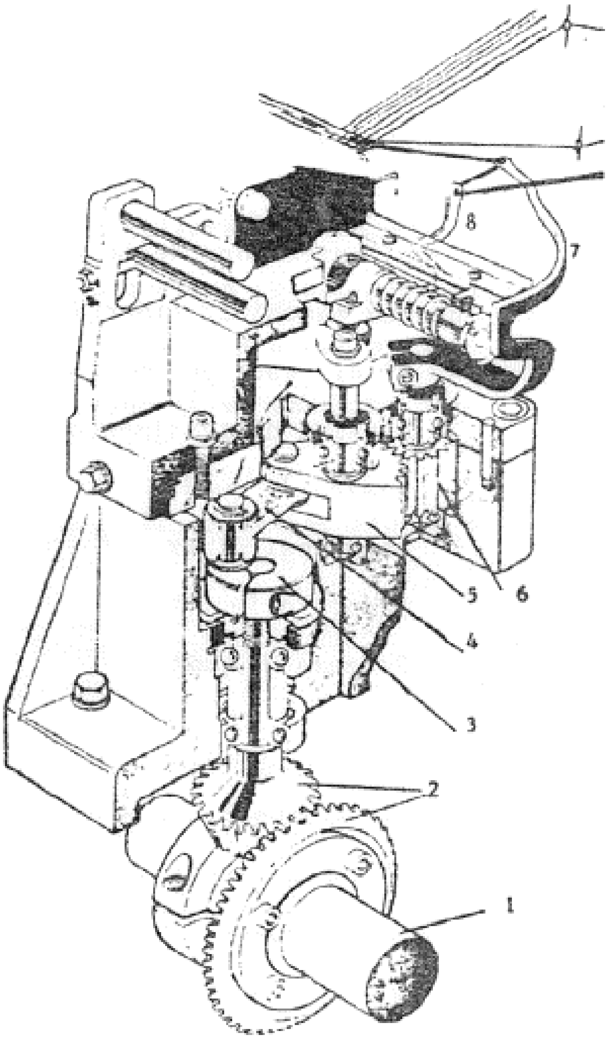


Fig. 72

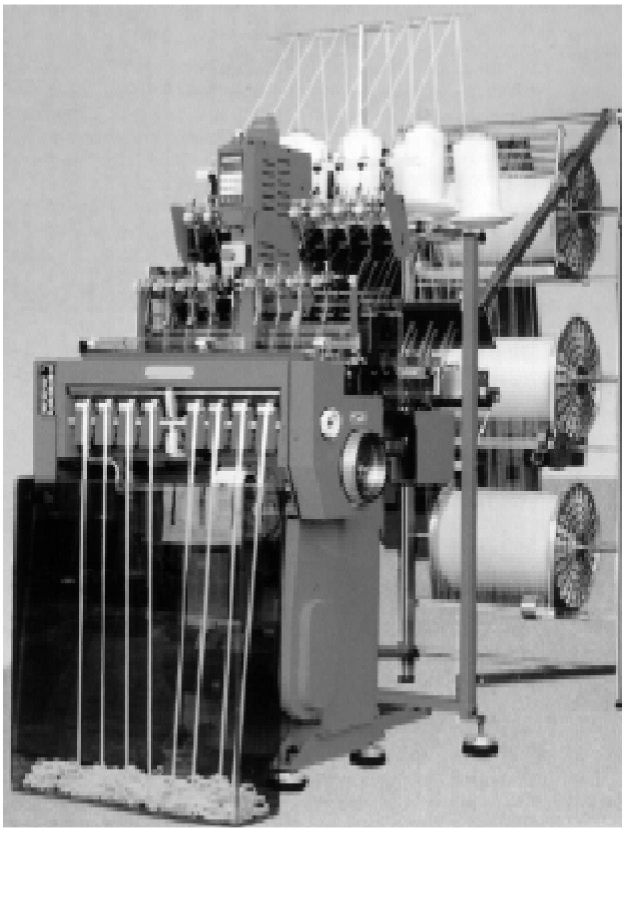


Fig. 73

Bearing structure of a weaving machine

The weaving machines are composed of two side frames in cast iron or steel, which are connected each other by cross members so as to create a firm bearing structure which can limit the vibrations and offer a good stability.
The machine members are covered by easily removable casings which protect them from dust and offer a passive safety to the operators.
The manufacturers have focussed their attention in last years on the study and on the analysis of the machine behavior at high running speeds; this permitted to optimize the movements and the balancing of the main members of the loom, as well as to reduce the vibrations transmitted to the floor and to the structure and consequently the noise.
Fig. 74 presents part of a bearing structure of a weaving machine; you can note the two side frames and the basis on which the dobby with the linkage for the heald control is applied. Fig. 75 shows instead the full structure of a weaving machine with various already installed components.

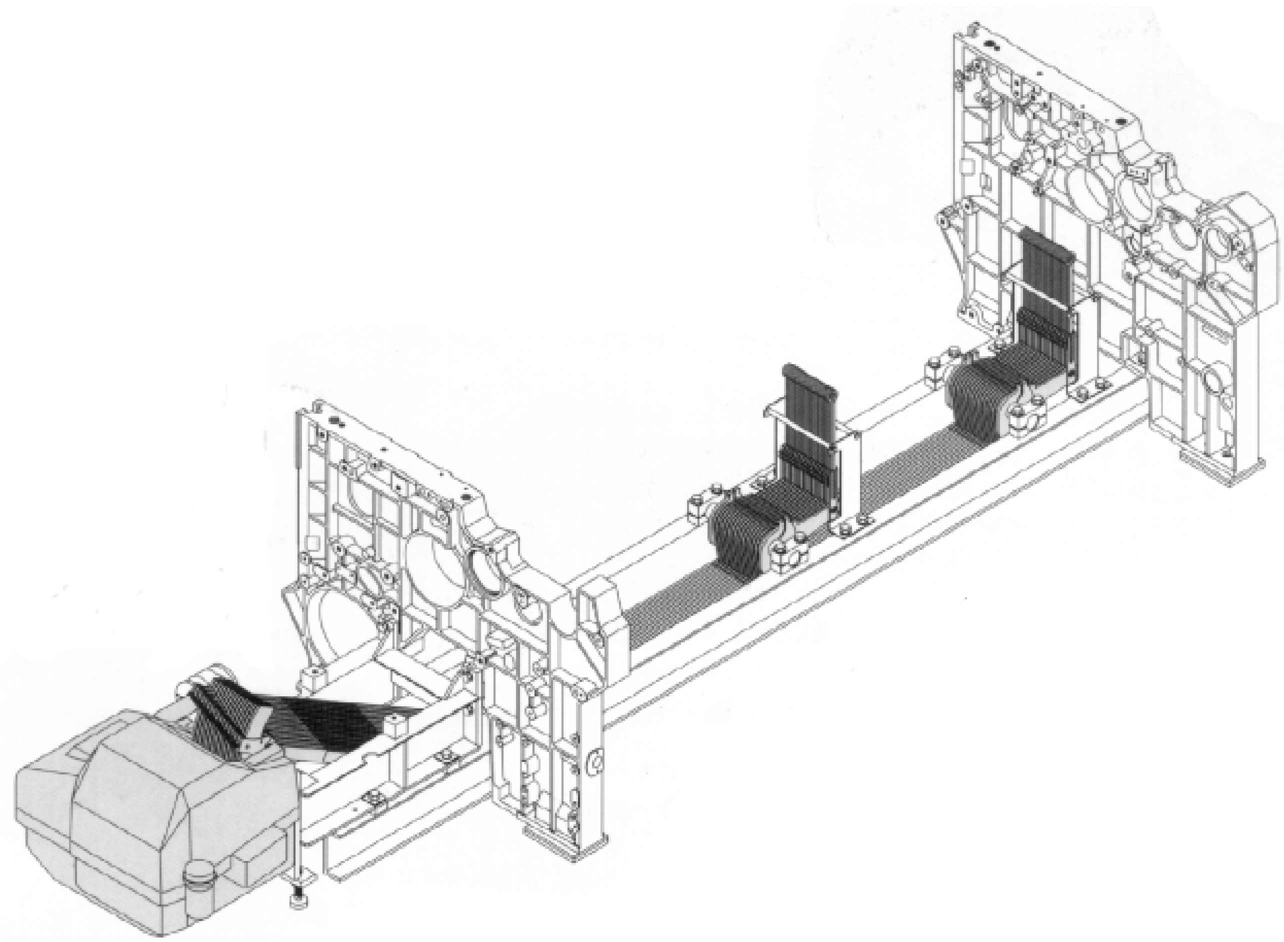


Fig. 74 – Skeleton of a weaving machine

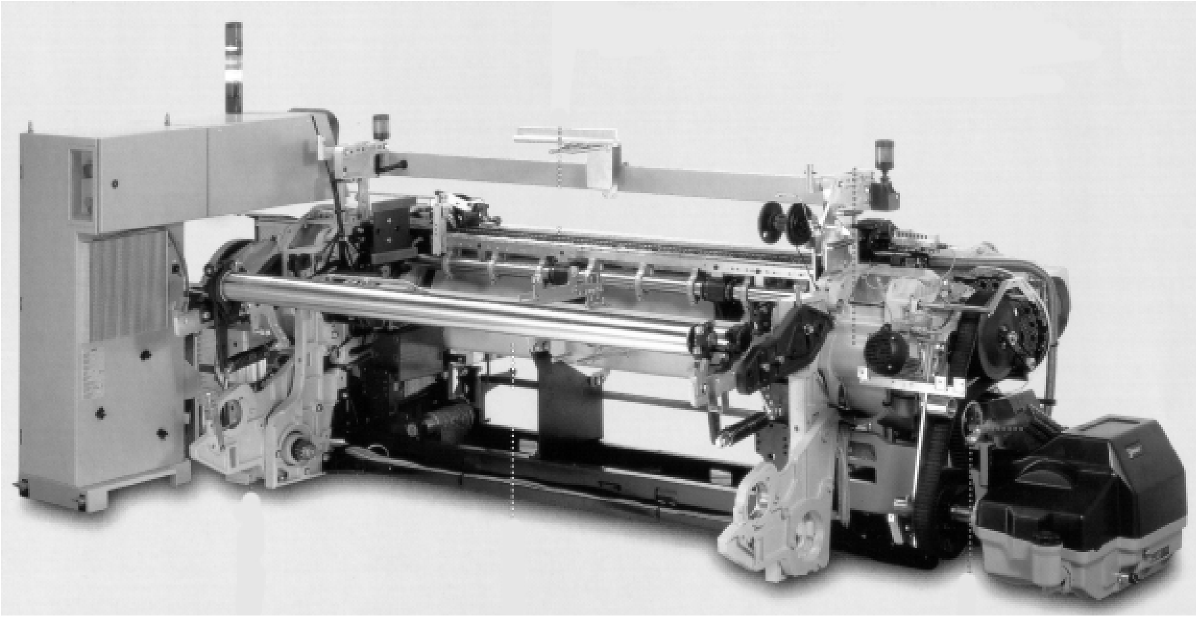


Fig. 75 – Skeleton of a weaving machine with various already mounted components

Warp let–off and fabric take–up

By now all modern weaving machines use integrated electronic systems which are operated by the drive and control unit of the machine. The warp beam and the take-up motions are driven by high precision servomotors equipped with speed reducer, connected with the machine's PLC through an encoder (a kind of electronic goniometer) and controlled through a closed adjustment ring. This ensures the synchronization of the weaving machine with the let-off and take-up motions (operating in series): practically the controller can know at any moment the exact position of the various devices.
A position sensor or a load cell signals at any moment the tension operating on the back rest roller and permits to adjust the let-off speed so that the tension remains absolutely constant from the start to the end of the weaving cycle. Furthermore the positions of the take-up and let-off motions during the critical starting phases can be adjusted to the running behavior of the material in progress, in order to avoid stripes on the fabric. Also the weft density can be varied without limitations during weaving and it is also possible to modify the warp tension by means of a simple keying in.

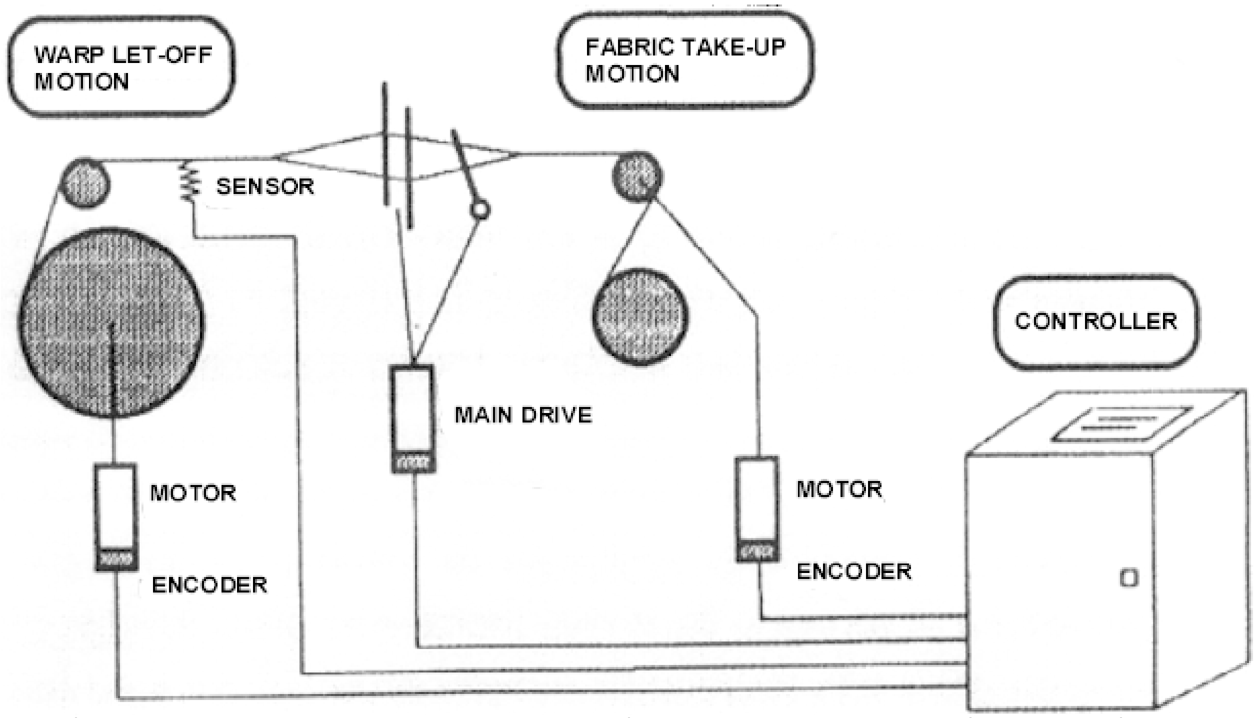


Fig. 76 – Integrated system with electronic control ″operating in series″ of the warp let-off and of the fabric take-up motions

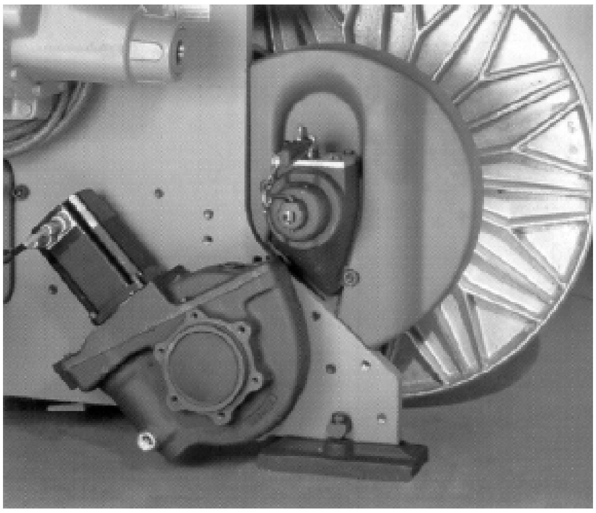


Fig. 77 – Servomotor for let-off motion drive

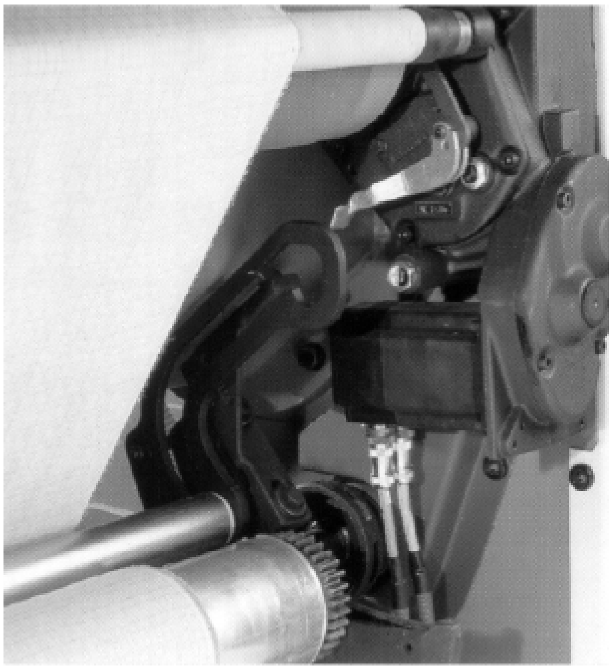


Fig. 78 – Servomotor for take-up motion drive

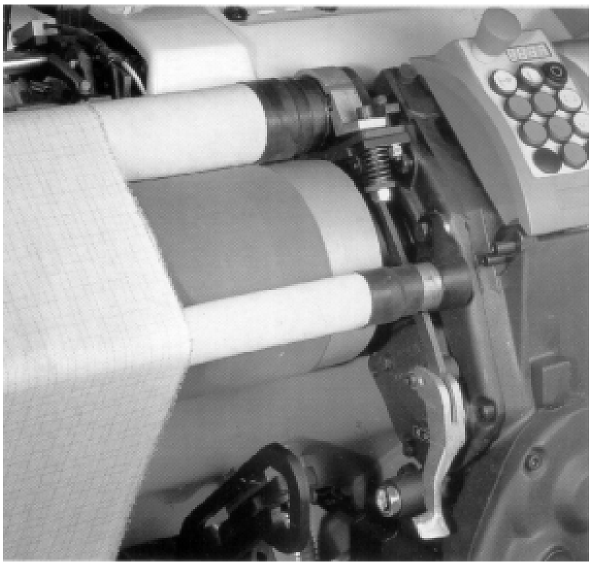


Fig. 79 – Take-up motion and guide/pressure rollers for the fabric take-down, which has to take place without any slippage. For this purpose the surface of the take-up roller is covered with an emery cloth and, when weaving delicate fabrics, with rough or smooth rubber

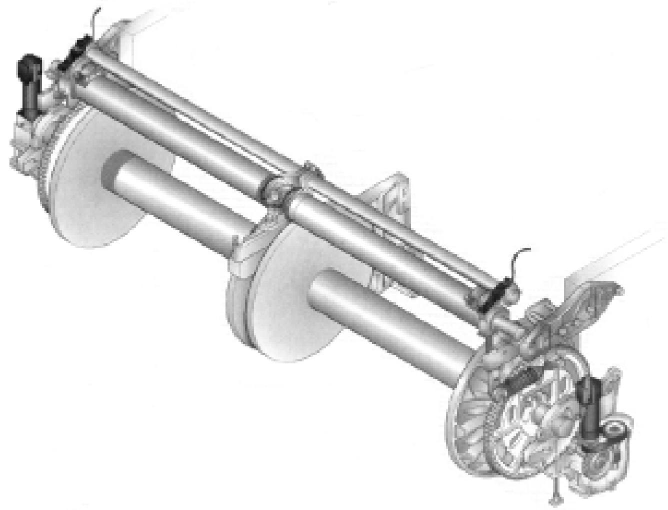


Fig. 80 – Example of double warp let-off motion for heavy weight fabrics or for fabrics with high warp yarn density (double width sizing machines and double capacity beam carriers would be required): the tension detecting system is independent on the two half-beams

Shedding machines

The angle which is formed by the raising threads with the threads remaining in low position is called **shed**; the shed must be as wide open as to permit the easy passage of the weft insertion element.
The shed can be obtained in two different ways:

- by moving the heald frames, the healds of which are crossed by the warp threads according to a pre-established drawing-in;
- by moving directly the healds through which one or several independent threads pass (figured or Jacquard weaving).

The machines used to form the shed are *cam machines, dobbies and Jacquard machines*.

Cam shedding or base weave machines

This kind of machine is employed for all fabrics produced with base weaves which have a pattern repeat of 10-12 threads and maximum 6-8 wefts.
These machines can operate either with positive or negative shaft motion. The principle of positive motion involves that the shafts are raised as well as lowered driven by cams. The negative motion

instead implies the motion of the shafts either in the upwards stroke or in the downwards stroke, while the backward movement is obtained through springs. The positive shaft motion has a conjugated structure which permits to control the shaft during all processing phases and to minimize vibrations, thus making cams suitable for any working load at high speeds.

Operation of a cam machine (positive motion)

This machine has conjugated cams fastened on a central shaft; the two profiles are read by small wheels mounted idle on a roller lever connected at its end with the heald frame rods.
The two cams are mutually complementary, so that when a cam presents its maximum eccentricity, the other cam presents the minimum eccentricity. This characteristic permits to push upwards the right wheel and at the same time to produce the same movement with the left wheel, but in the opposite direction.
The displacement of the roller lever causes the raising of the shaft.
In the case of balanced weaves, i.e. plain weave, twill weave, diagonal 2/2, the two cams are identical, but have each towards the other a phase angle which is established already during their construction.
For the production of the remaining weaves, the overturning of the two cams permits to obtain the opposite effect, e.g. changing over from warp to weft twill.
The cam units are as many as the working heald frames and the shaft modifies its running speed according to the weave to be produced, consequently the speed corresponds to the revolution number of the machine/n and the figure 360/n shows the angle at which a weft of the repeat is inserted (n corresponds to the number of repeat wefts).

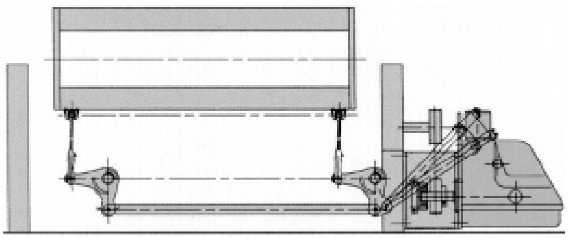


Fig. 81 – Assembly scheme of the cam machine

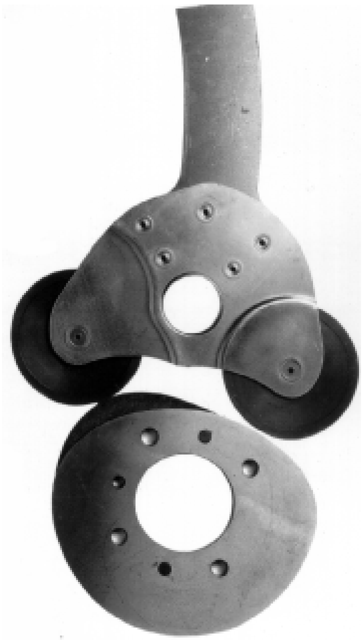


Fig. 82 – Conjugated cams with roller lever

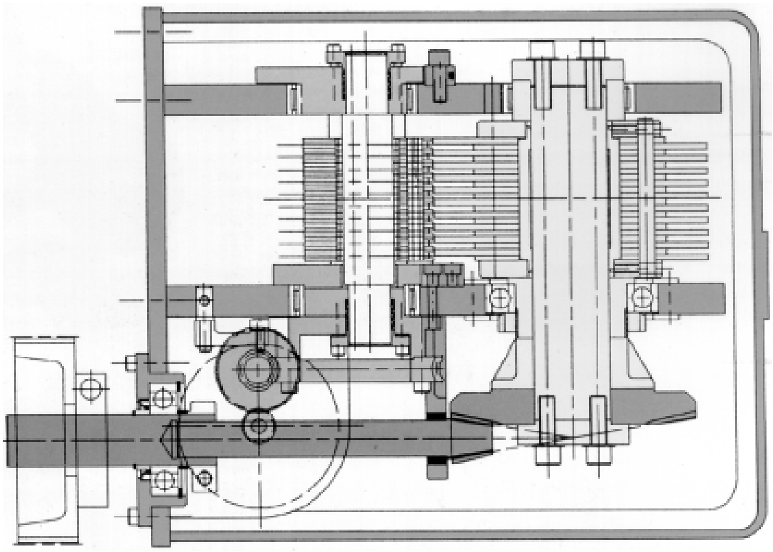


*Fig. 83 – **Cam machine:***
1 – driving shaft
2 – toothed bevel gear pairs
3 – group of conjugated cams
4 – pin on which roller levers are set up.

Dobbies

Dobbies are used for the production of plain or flat fabrics, that is of fabrics characterized by maximum 28-32 threads in the weave repeat.

Dobbies can be divided into:

According to the working principle:

- **Hattersley dobbies**
- **rotary dobbies**

The Hattersley dobbies are dobbies which control the movement of the heald frames through rods and rocker levers. The rotary dobbies attain the raising and lowering of the heald frame through rotating members.

According to the raising motion of the heald frames:

- **dobbies with positive drive**
- **dobbies with negative drive**

The positive dobbies are dobbies in which both raising and lowering heald frames are driven directly.
The negative dobbies are dobbies in which the heald frames are driven directly either only in the raising phase or only in the lowering phase.
The dobbies are always mounted in bottom position, both if they are with positive or negative drive.
Only in the case of water jet weaving machines, the dobbies are generally mounted in upper position to avoid the intrusion of water into the mechanisms (Fig. 84–85).

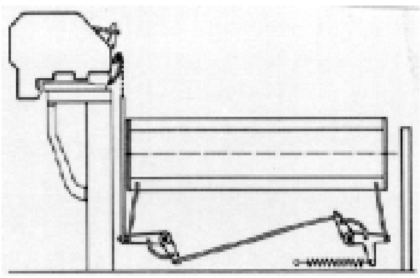


Fig. 84 – Negative dobby (upper position for water-jet weaving machines)

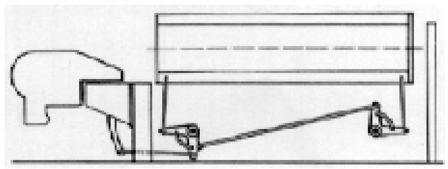


Fig. 85 – Positive dobby.

According to the card reading system:

- **dobbies with endless pattern card**
- **dobbies with magnetic card**

Operation principle of a dobby

Today the rotary dobby is, from the technological point of view, the most advanced dobby available on the market.

It consists of a central shaft on which the driving bars are positioned.
On a follower ring an eccentric plate is mounted; the plate is constrained within a block which is pivoted with the control levers of the rods.
Under normal working conditions, that is with the heald frames in bottom position, there is no connection between the follower ring and the plate; the connection can be obtained by inserting a slider which runs in proper guides.
The central shaft is driven by a modulator which has two stop times situated each other at 180 degrees ; at this very moment the key can be controlled according to the design to be produced.

Fig. 86 – Rotary dobby

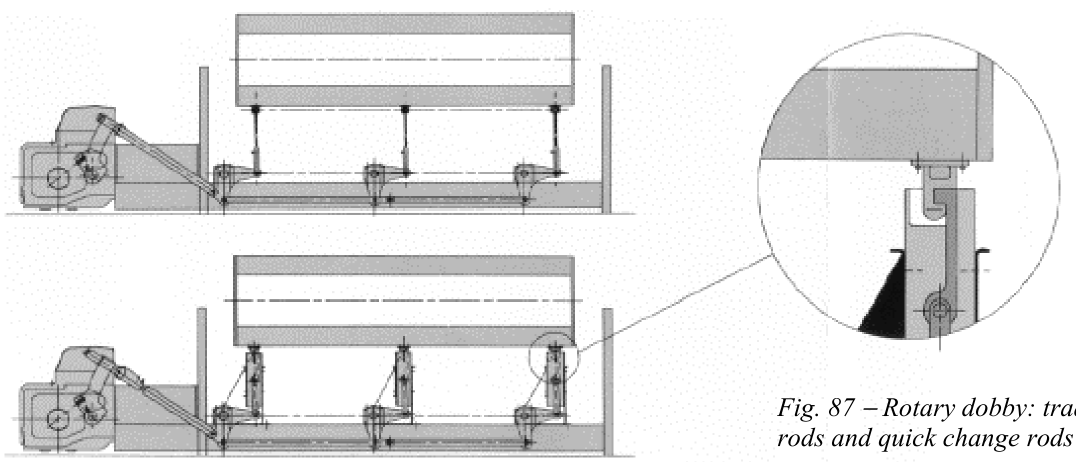


Fig. 87 – Rotary dobby: traditional rods and quick change rods

The insertion of the slider causes a 180° rotation of the plate which, thanks to the link, imparts a force on the lever controlling the rods of the heald frame, causing its passage from the initial position to the opposite position and consequently the raising of the heald frame.
As soon as such position is reached, at the subsequent shaft stop a new signal is emitted: if the heald frame has to remain in raised position, the key is pulled out, thus blocking it in upper position and leaving it motionless there till emission of a new order, which can be in same or opposite direction.
If the direction of the order remains the same, the slider is taken out and the heald frame remains motionless in upper position; if the order has opposite direction, the slider is set to work and generates a movement in opposite direction to the previous heald frame lowering.
The design is controlled by the microprocessor on board the machine, which transmits the inputs to a series of electromagnets which shift the sliders to the two said positions.
The rotary dobby, which is a machine with positive drive, has replaced all other models based on different operation principles.

Jacquard machines

The name Jacquard machines originates from the designer who improved its operation; today the name ″Jacquard″ is used to identify all machines with a capacity higher than 28-32 threads, which are therefore used to produce figured fabrics.
The indication of the capacity of the machine, which in the past was used to differentiate the various machine models, has today no significance, as the hook number is no more strictly related to the mechanical structure of the machine.
Jacquard machines were initially classified as follows:

- **Jacquard machines**
- **Vincenzi machines**
- **Verdol machines**

At present only Verdol machines and electronic Jacquard machines are still on the market.

Jacquard machines can be classified as follows:

According to card reading system:

- **dobbies with endless pattern card reading system**
- **dobbies with electronic reading system**

The endless pattern card system is gradually disappearing in favor of the electronic system.
Modern Jacquards are exclusively double lift machines (which means that the thread floating over several subsequent wefts remains always in upper position and does not go down to sley level) with electronic control (with magnetic bearings).
The machines with card reading system (Jacquard) or with endless pattern card system (Verdol) have practically disappeared from the market.

According to machine capacity, i.e. to used hook number:

- **Verdol type machines: 448 – 896 – 1344 hooks**

- **electronic machine with modules permitting following load capacity: 5120 – 6144 – 8192 – 10240 – 12288 hooks.**

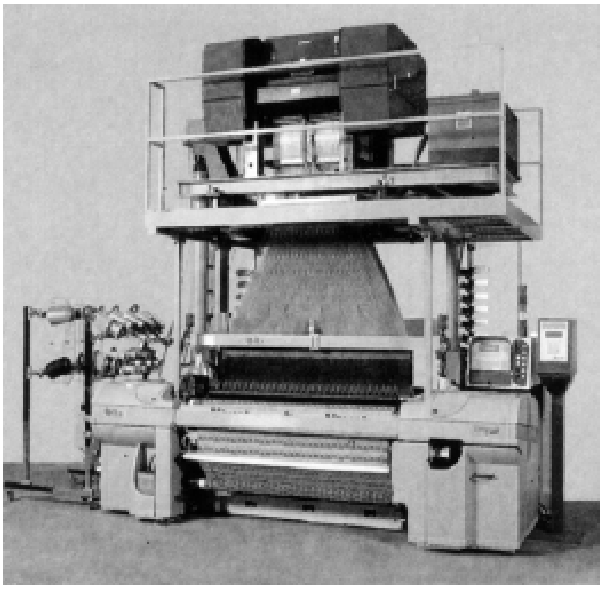


Fig. 88 – Jacquard machine with deck

Electronic Jacquard

In these machines the traditional hooks have been replaced by electro-mechanically operated modules which are driven and controlled by an electronic program. The Jacquard machines available on the market are double lift machines and have in respect to mechanical Jacquard machines following advantages:

- **easy maintenance** owing to following reasons: no point needing lubrication, few moving parts, modular construction and thus easy access;

- **low vibration even at high speed;**

- **reduced setting time**, as the machine is electronically controlled and therefore no paper is needed.

Fig. 89

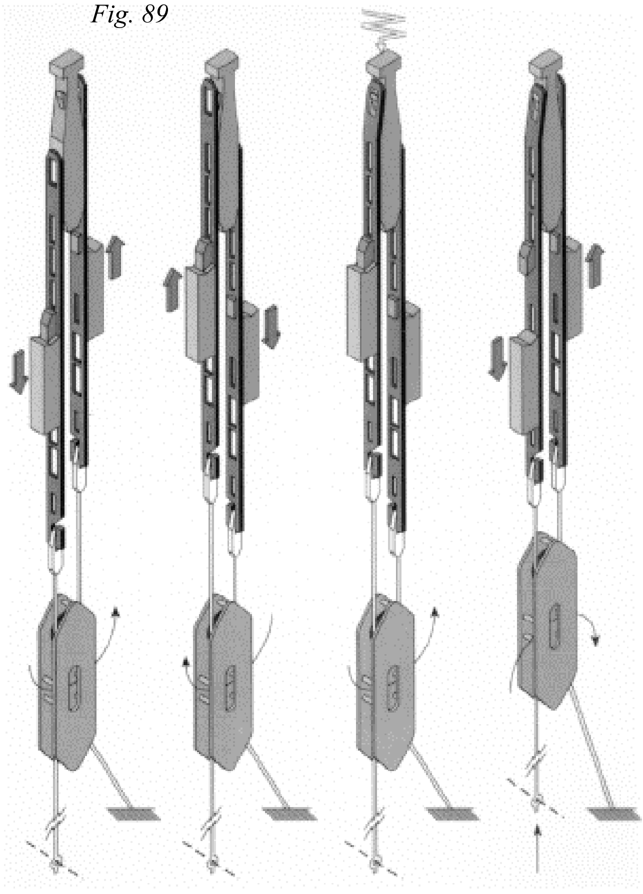


Fig. 89 and 90 show the two most widely used models of electronic Jacquard machines.

In Fig. 89 each module is composed of 48 hooks; by combining together several modules, it is possible to attain the various capacity loads. The hook is flexible and has windows to allow its hooking-up to the magnet.
The machine operates as follows: in the first two sequences of Fig. 89, the magnet (controlled by the program) does not receive any impulse and the double pulley maintains the warp thread in bottom position, although the hooks move upwards and downwards together with the griff knives (the rotation of the upper pulley compensates the movement

of the hooks). The last two sequences of Fig. 89 show that, when a
thread needs to be raised, the magnet receives the impulse and the flexible hook hooks-up to the magnet. This causes the lifting of the double pulley, as in this case it is not possible to make any compensation.

In the model shown in Fig. 90, the elements raising the heald frames 18 and 19 operate in opposition one another. In figure A the knife 18 is positioned at the upper dead center, whereas the knife 19 is at the bottom dead center.
At the end of the stroke, the movable hooks 6 connected with the suspension cable 9 lean alternatively the upper end of the check hooks 4 on the electromagnet 5.
Thre are two cases:

1) The electromagnet 5 is powered (case A):

- the check hook 4 remains ″stuck″ to electromagnet 5.
- The movable upper hook 6 goes down together with knife 18.
- The lifting cord 10 goes up or remains in bottom position.

2) The electromagnet 5 is not powered (case C):

- owing to spring 3, the check hook 4 hooks up the movable upper hook 6, which therefore remains in upper position.
- The lifting cord 10 goes up or remains in upper position.

The body of the rocker arm 7 linked to the fixed point 11 reinstates a shifting of the lifting cord 10 equal to that of knife blades 18 and 19.

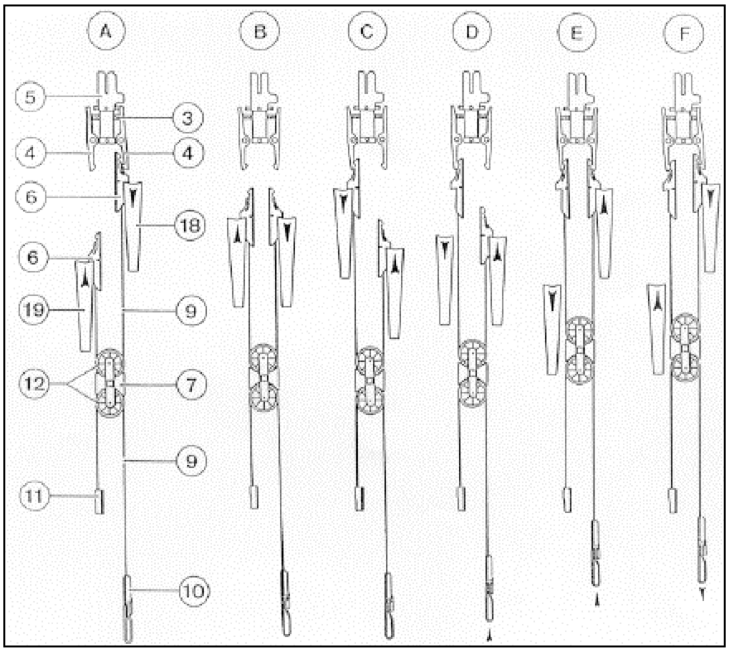


Fig. 90

Drive and control of weaving machines

The latest weaving machines are equipped with microprocessor or PLC units which ensure continuously the control, the drive and the monitoring of the various machine members and of the various functions.
A variety of electronic devices and sensors permits the collection and the processing in real time of the main production and quality parameters. These parameters can also be recorded and transferred through memory cards to other machines or stored for future use (fig. 91). The control unit can be connected with outer units (terminals, servers, company managing system) to transmit/receive data concerning both the technical and productive management and the economic-commercial management (fig. 92). All this facilitated considerably the weaver's work in respect to machines of previous generation, and enabled to improve the production yield and the product quality.

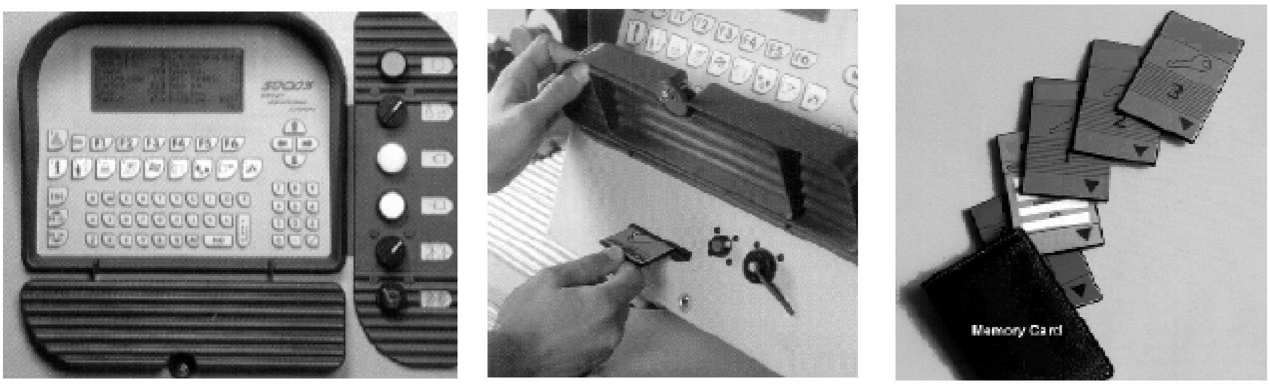


Fig. 91 – Board computer equipped with memory card

The main operations which can be carried out by simply keying in the value of the desired parameter on the keyboard of the electronic control unit are:

- selection and modification of the weft density with running machine, as both the motor driving the take-up roller (sand roll) and the motor driving the warp beam are electronically controlled and synchronized one another. This permits also to combine a programmed automatic pick finding, obtained through correction programs based on the characteristics of the fabric in production, in order to prevent formation of starting marks (after machine stops);
- electronic selection and control of warp tension through a load cell situated on the back rest roller, which last detects continuously the tension value. This permits the processor to control the movements of the warp beam and of the take-up roller, ensuring a constant tension throughout the weaving operation (fig. 93);
- programming of the electronic dobby and of the electronic weft colors selector;
- programming and managing of nozzle pressure and blowing time in air jet weaving machines;
- selection and variation of the working speed, as the machines are provided with a frequency converter (inverter) which permits to modify at will the speed of the driving asynchronous motor;
- statistics;
- monitoring;
- managing/programming of all machine functions.

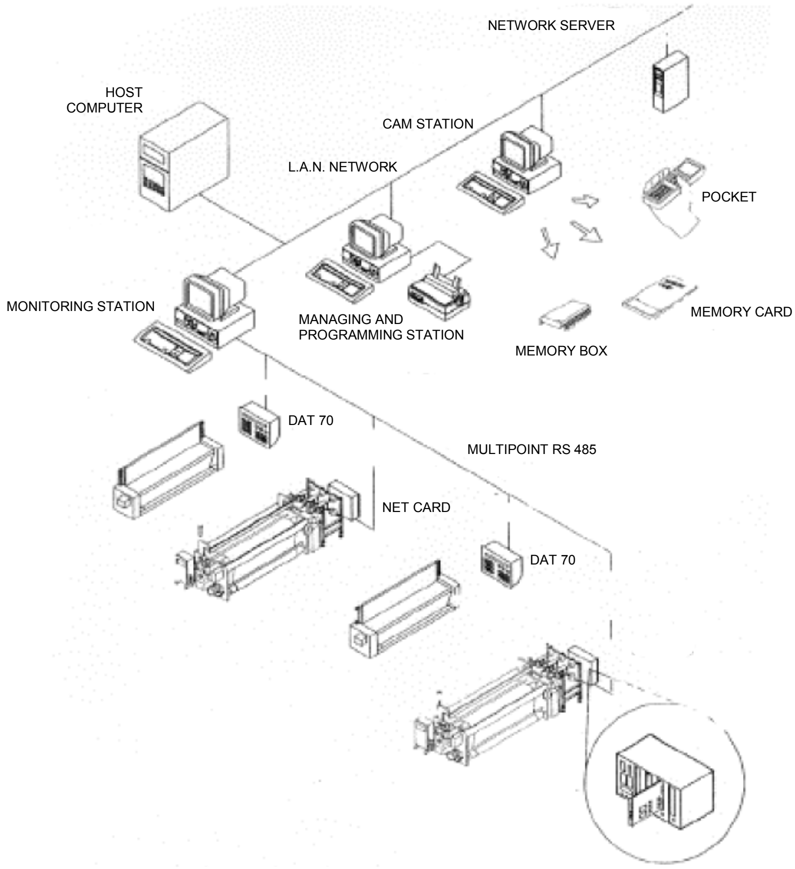


Fig. 92 – Example of a modern monitoring and control network

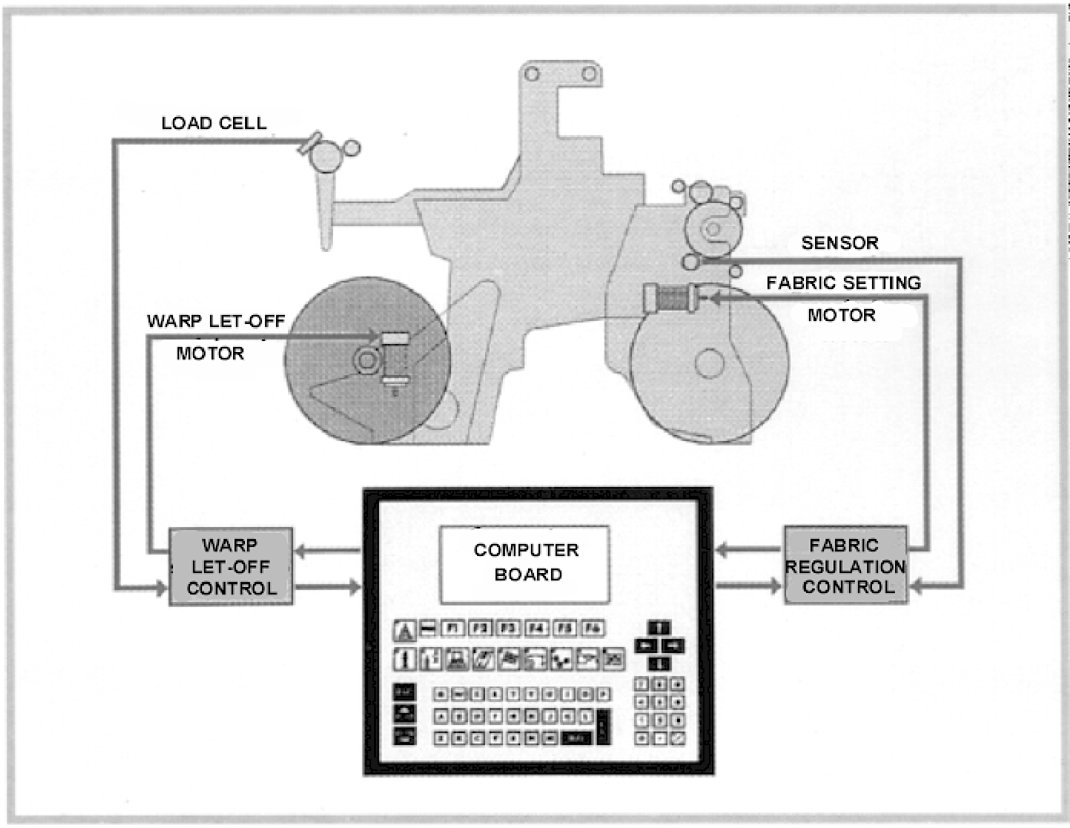


Fig. 93 – Electronic detecting and control system on thread tension. Setting and modification of tension and weft density directly via board computer

Other equipment

With a view to increase the efficiency and the flexibility of the weaving machines, the manufacturers have made considerable efforts to find solutions capable of simplifying and speeding up the operations and the machine settings at style changing and to permit coping better with particular production requirements.

The ″Quick Style Change″ (QSC)

The weaving mills which produce small quantities per style (high quality clothing) can increase the weaving efficiency by optimizing the style change. The Quick Style Change consists of a series of operations as shown in Fig. 94, which need to be carried out as quickly as possible.
By suitably designing the weaving machines, using new equipment and organizing systems, this operation is accomplished in about forty-five minutes by a single operator, thus saving a lot of time (fig. 95).

Operations involved in style change (QSC) and in warp change (QWC)	Warp change	Change of reed width	Change of heald frame number	Change of heddle drawing-in	Change of thread number
QSC	Yes	Yes	Yes	Yes	Yes
QWC	Yes	No	No	No	No

Fig. 94

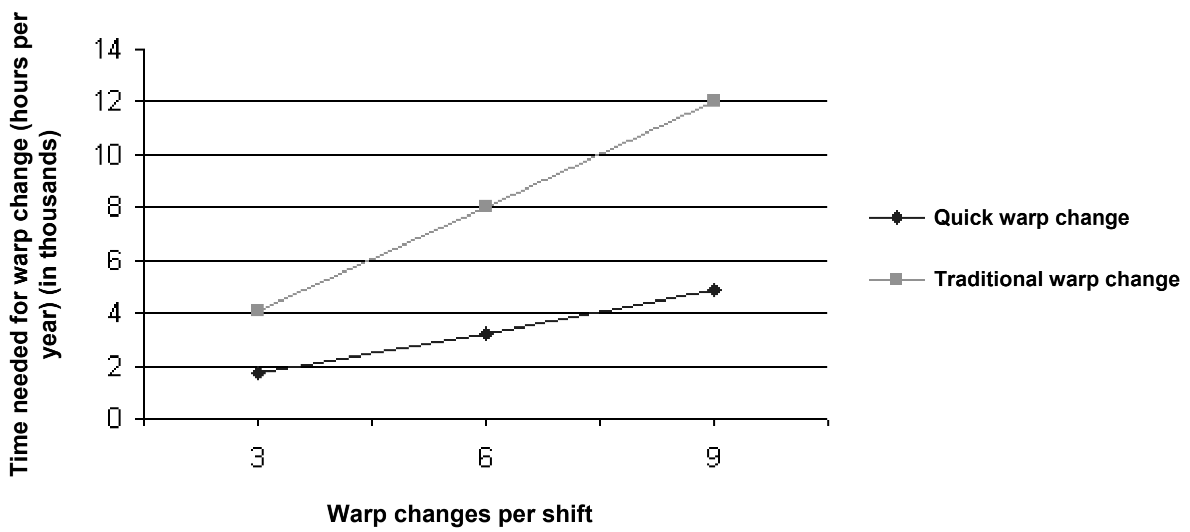


Fig. 95 – Time needed for warp changes during one year in a weaving mill with about 150 machines

The quick warp change (QWC) consists instead only of the replacement of an empty beam with a ready full beam, of knotting the new threads with those of the run out warp with an automatic tying-in machine, and of the forward movement of the warp beyond the reed, to eliminate the knotted zone.

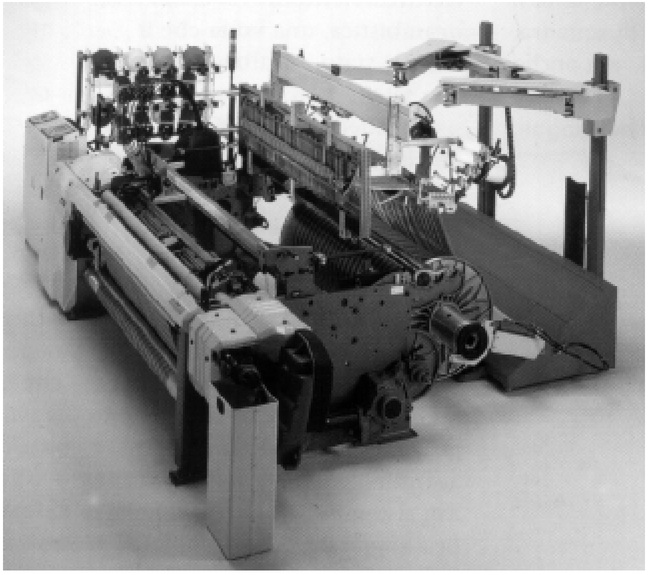
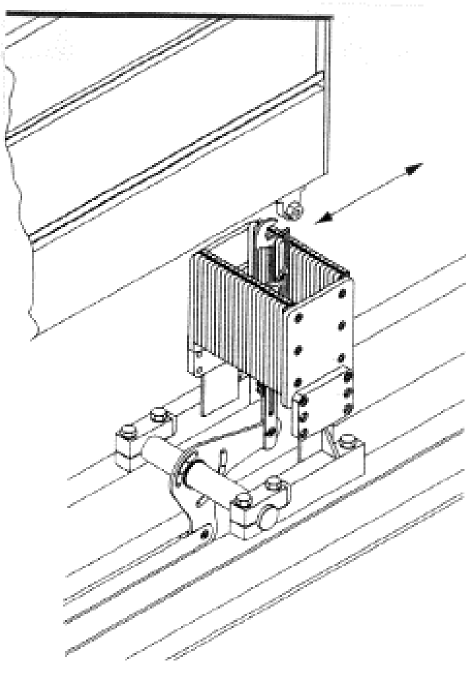


Fig. 96 – Quick style change

Figures 97, 98 and 99 exemplify solutions which make operator's moves easier and quicker.

Fig. 97 – ***Quick heald frame hooking:*** *this operation permits quick hooking and unhooking of the heald frames by their lateral shifting, avoiding manual operations in the zone below*



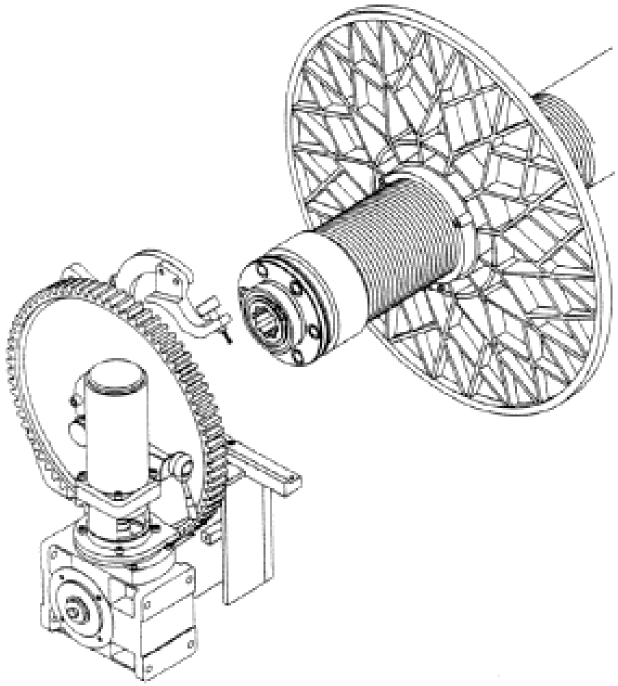


Fig. 98 – ***Quick beam change:*** *this operation is facilitated by the quick insertion of the beam's end through grooved profile driven by an eccentric, while leaving the gear on board the weaving machine; the beam blocking is guaranteed by a quick gripping system*

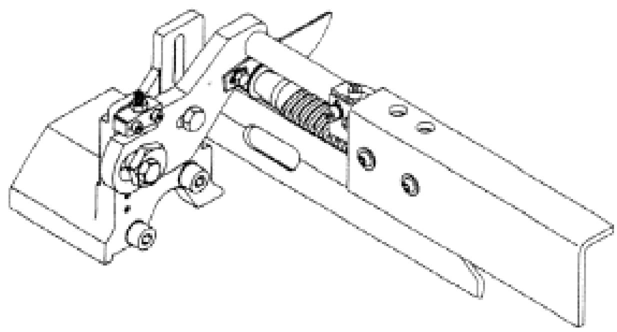


Fig. 99 – ***Quick temple positioning:*** *this operation permits the immediate re-positioning of the temple during re–assembling*

Reduction of the number of warp and style changes

In addition to QSC and to QWC, another possibility to reduce the incidence of the setting-up times is the reduction in the number of warp changes by using large diameter warp beams and take-up devices for large batch rolls, both installed outside the weaving machine, which besides for these aspects is also suited to particular weaving requirements. These machines are designed for a cost-effective production of standard fabrics or of particular fabric categories (Fig. 100 and Fig. 101).

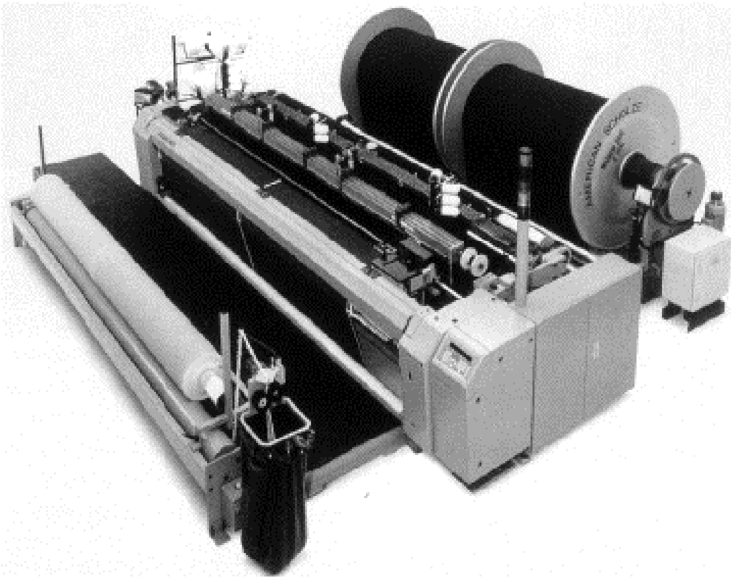


Fig. 100 – Projectile machine equipped with outer winding unit into large batch rolls and with double outer beam of large size (1600 mm). This ensures maximum warp duration, good accessibility and easy operation

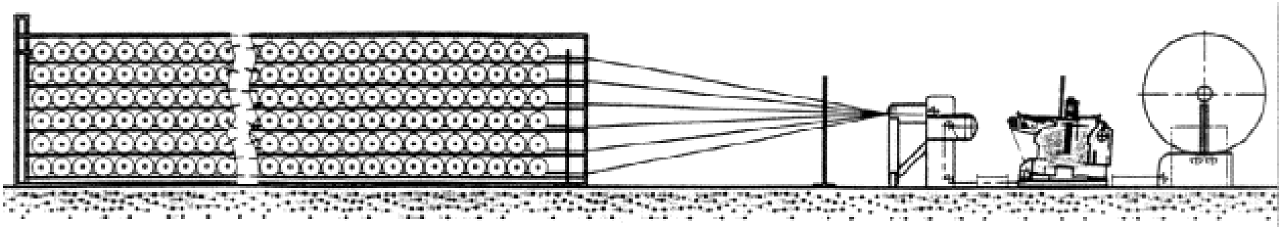


Fig. 101 – Weaving machine equipped with creel feeding and outer take-up device on large batch rolls (2000 mm diameter), used only for particular needs, like technical fabrics

Weaving machines of new design

Another way to increase production is to design and manufacture particular weaving machines which can offer very high weft insertion rates.
An example is the machine in Fig. 102. This machine has two fronts and its members are positioned according to a vertical development, with the two warp beams situated in bottom position and the take up beams for the large batch fabric rolls placed in top position. The weft is inserted by two air jet systems, each per machine front.
The machine has been designed to produce widely used fabrics in the basic weaves, with a production potential as high as over 5000 m/min of inserted weft. The production costs are limited thanks to the high automation level, to the ergonomic position of the various components which facilitate the machine management and control, and to lower floor space.

Another example is the machine in Figures 103, 104, 105, a multiphase weaving machine with multi-linear shed formation. This machine has a completely new design and permits the contemporary formation of a series of small sheds placed in sequence in warp direction. In each shed, air jet systems insert the weft. This way 4 wefts can be inserted at the same time. A series of reeds, similar to the traditional reeds, brings the wefts gradually near to the cloth and beats them. Although the yarn unwinding speed from the cones is low because this operation takes place continuously, the insertion performance is extremely high – over 5000 m/min – and is susceptible of increasing further. As a matter of fact, also this machine has been designed for the mass production of standard fabrics in basic weaves at competitive costs. However the process is so innovative, that it has still to find a total validation.

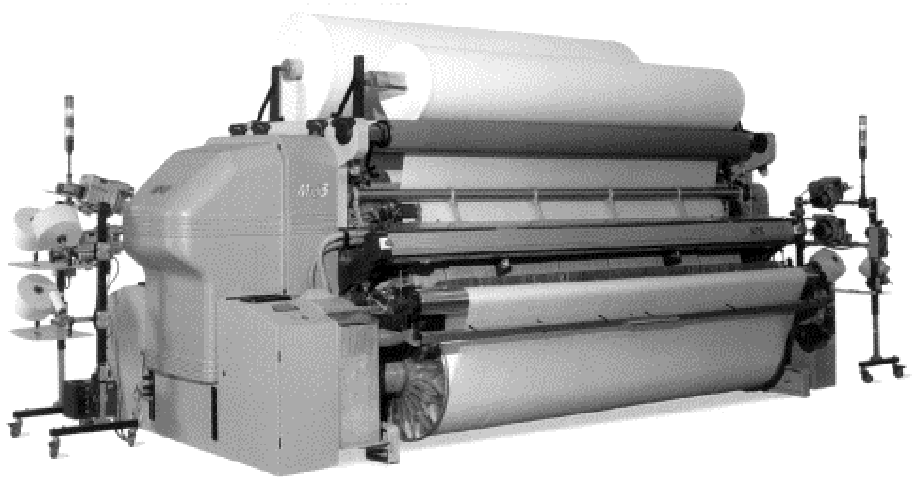
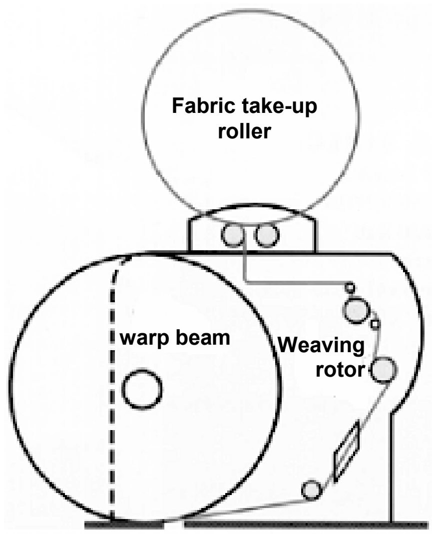


Fig. 102



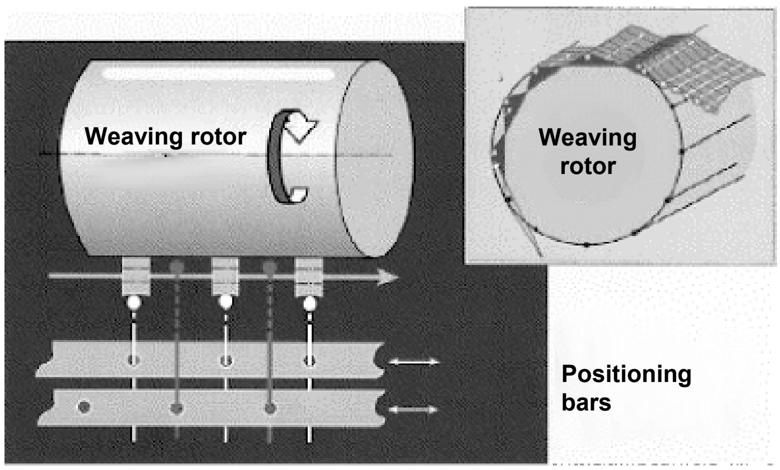


Fig. 104 – The elements of the weaving rotor form, by plunging one after the other into the warp yarn sheet, forming a sequence of sheds. The positioning bars select the threads to be raised through movements of only few millimetres.

Fig. 103 – Structure of the multiphase multilinear weaving machine

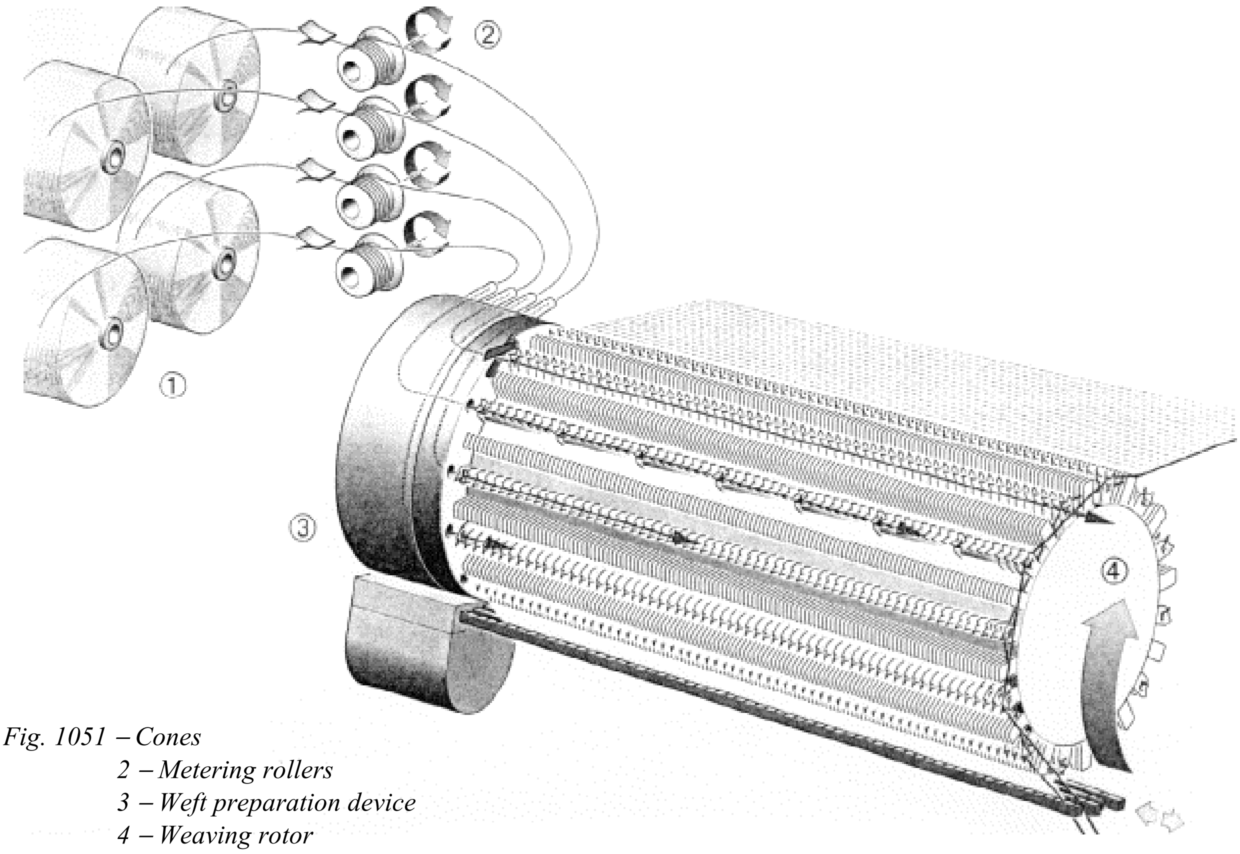


Fig. 1051 – Cones
2 – Metering rollers
3 – Weft preparation device
4 – Weaving rotor

Weft feeders

These intermediate feeding devices, which are also called weft storage feeders or weft accumulators, play today an important role in the weaving machines where the weft is unwound overhead from the cone and is subjected to abrupt accelerations due to the drawing-off tension exerted by the insertion element (rapier, projectile, fluid). The balloon which is formed at each insertion can cause coil sliding and snarls, owing to the difficulty of braking adequately the yarn and to the high unwinding speed of the yarn from the cone, which results into abrupt stresses, varying with diameter and speed variation. The present weaving speeds made thus absolutely necessary the use of an auxiliary apparatus placed between the cone and the insertion device. This apparatus positions the thread in a way as to favour its unwinding under lower stresses, and at the same time takes off from the package the necessary thread length, also making the most of the dead times between an insertion and the other, therefore with lower unwinding speeds and more continuously.
In the air-jet or water-jet machines, we should better speak of thread length pre-measuring devices, as the feeder has the task of winding on its own drum a thread length which corresponds exactly to an insertion. In modern pre-measuring devices, the thread length wound on the drum is controlled by opto-electronic sensors.
The feeders are supplied together with various outfits and adjustment possibilities, which vary according to the yarn type and count and to the insertion system used. Each of them is equipped with an independent motor, which speed can be modified within a wide range of values. The feeders can also be connected with the driving unit of the weaving machine and interact with it.

Their general structure is presented in the scheme as per Fig. 106: the thread is taken off from the cone by a thread guide 1 composed of an eyelet obtained on a ring which is put in rotation by an electric motor M. The thread guide winds the thread on a drum 2, consisting of a series of fixed segments alternated with a series of oscillating segments. These segments, through their movement, move the coils forward along the surface, positioning them in a regular way and keeping them separated one from the other.
At the moment of the insertion, the thread unwinds from the drum with a torsional movement opposite to the winding movement, passing through a braking system 3 which has the task of bringing the thread tension to the desired value and of maintaining it constant, and finally through another thread guide 4. A photocell system or any other system, suitably adjusted, will bring about the length of the thread reserve which is wound on the feeder's drum.

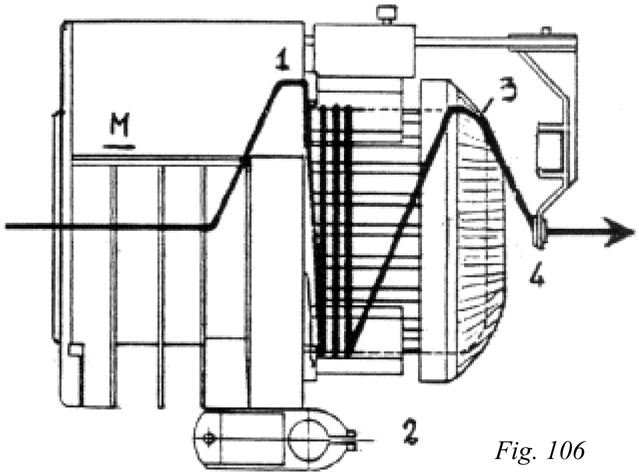


Fig. 106

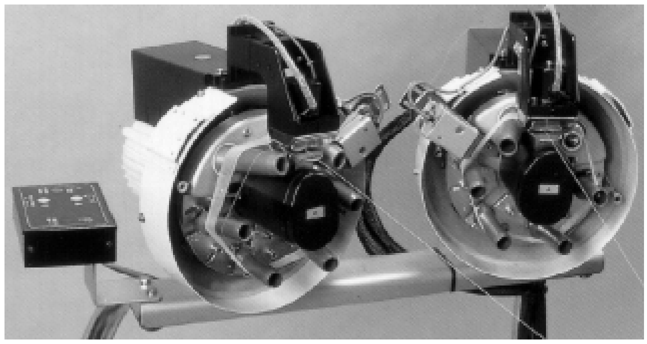


Fig. 107 – Pre-feeders for water jet machine with microprocessor controlled weft selection

Weft and warp control

Weft control

The weft stop motion controls the correct insertion of the weft into the shed, that is whether the weft has broken or be too short to reach the opposite end of the shed (short weft). In the case of rapier and projectile weaving machines, the mostly used device is provided with **piezoelectric crystals**. These crystals have a double quality: **if an electric charge passes through them, they vibrate, or vice versa if they are made vibrate, they produce a light electric charge.** This second property is used for the weft insertion control. This device, if it detects a correctly inserted weft, produces a light electric charge. As this signal is too weak, it is first amplified and then controlled against a sample signal: if the signal corresponds, nothing happens.

*Fig. 108 – **Piezoelectric electronic weft stop motion** with integrated amplifier, which at its output emits two logic signals to indicate the broken weft or weft excess in the insertion.*

Otherwise, the absence of the charge is interpreted as a broken weft and the weaving machine stops. At this point the automatic pick finding device enters into action and brings the machine back to the shed where the fault occurred. In this connection you must consider that, although the stop signal is given quite quickly, a certain technical time for stopping the loom is required. During this time, although the weft presenting device is standing, the loom moves forward with some strokes which are compensated recovering tension and space through the reverse running of the evener rollers.

In the case of fluid jet machines, it is preferable not to hinder the weft fly, therefore optical sensors are used which do not touch the weft. As already mentioned, in the case of the air jet machines (at the moment only for them) there is a device which permits to restore automatically the broken weft and to start the loom. This mechanism permits to go on weaving if the problem takes place inside the shed. However, if defects take place in the pre-winding drum or between this and the cone, it is appropriate to have on board the machine the device which permits to select automatically the cone being processed. This system enables to bypass the pre-winding drum which has problems and to select a reserve drum which is standing until that moment. The machine does not need long stops and the operator can intervene easily to remedy the problem. Should the same fault take place again on the new pre-winding drum, this will be excluded in favour of the first drum.

The optical sensors are primarily infrared photocells suited to detect the presence of the thread or the quantity of thread accumulated in a prefixed zone.

An example of these devices is the sensor for weft control on air jet weaving machines, which is briefly described in the following.

This device, which is designed to control the correct weft insertion into the shed of an air jet loom, has the task of stopping the machine in case of incorrect insertion.

The sensor is placed on the shaped reed at the desired height in the zone of weft arrival; it reads the presence of the thread when its front free end arrives in the sensor's measuring range and crosses it.

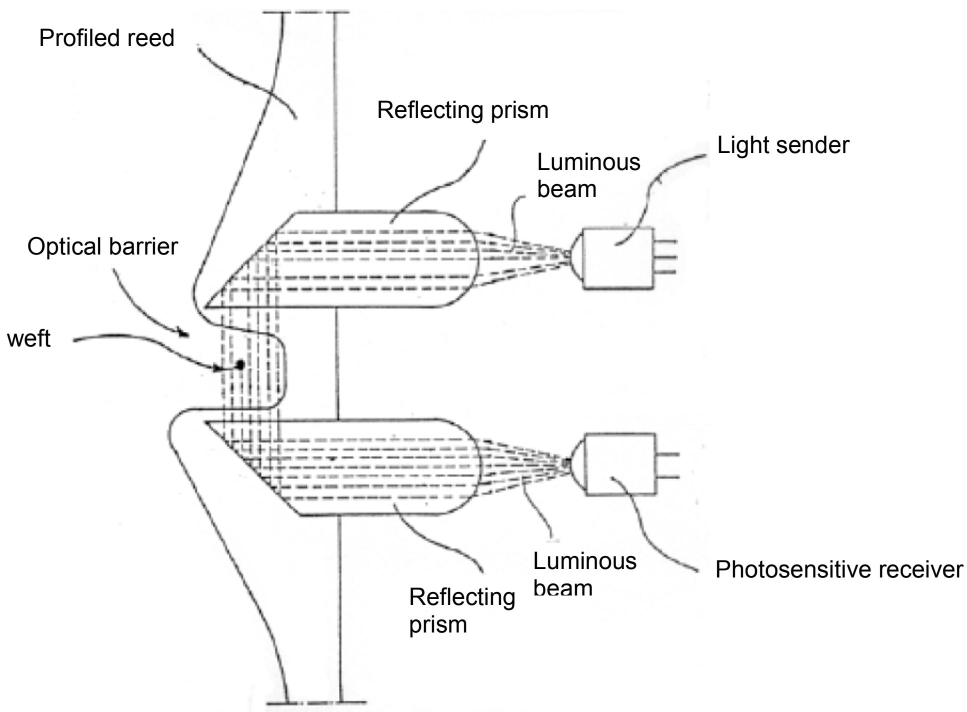


Fig. 109 – Optical sensor applied on an air jet weaving machine

The two photo-elements are opposing as schematically indicated in Fig. 109 and constitute an optical barrier which is disturbed by the weft thread when it is crossed by this thread.
In the case of air jet machines for staple yarn weaving, an opto-electronic weft stop motion in twin arrangement can be delivered. While the first of the two weft stop motions serves as support for the machine control, the second one records the weft threads broken in the shed or expelled.

Warp control

The supervision of the warp threads is an essential factor for the fabric quality.
The device used is called warp stop motion; it *stops the running of the weaving machine at each thread breakage or even when the thread becomes slack*, that is when the thread gets a tension level considerably below normal level (delicate fabrics).
The warp stop motions generally used today employ electrical or electronic detection systems.

Electric warp stop motion

The operating system is the following (Fig. 110): each warp thread is passed into the bottom slit of a metallic drop wire 2, which this way is supported by the thread under tension. Through the top slit of the drop wire passes the contact rail 3 composed of an U-shaped outside coating in stainless steel, of a strip of insulating material and of a flat conductive inside blade in nickel-plated copper, provided on the upper part with a toothing.
The contact rail 3 is part of a low voltage electric circuit, of which the drop wire 2 acts as circuit breaker.

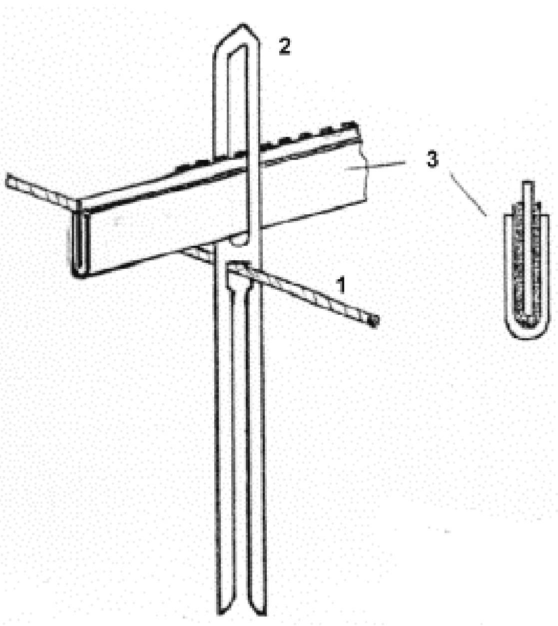


*Fig. 110 – **Electric warp stop motion:***
1 – Warp thread
2 – Metallic drop wire
3 – Contact rail

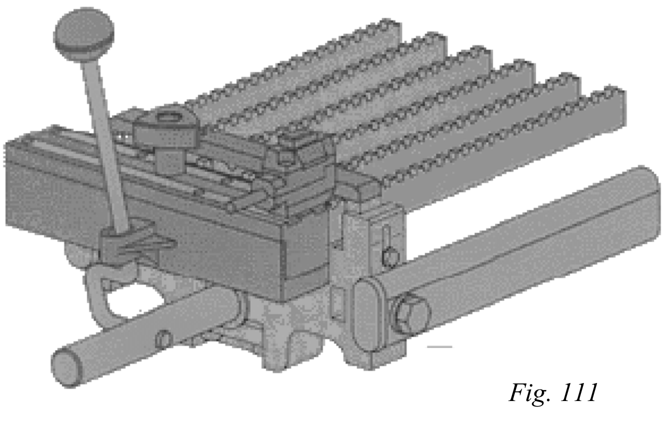


Fig. 111

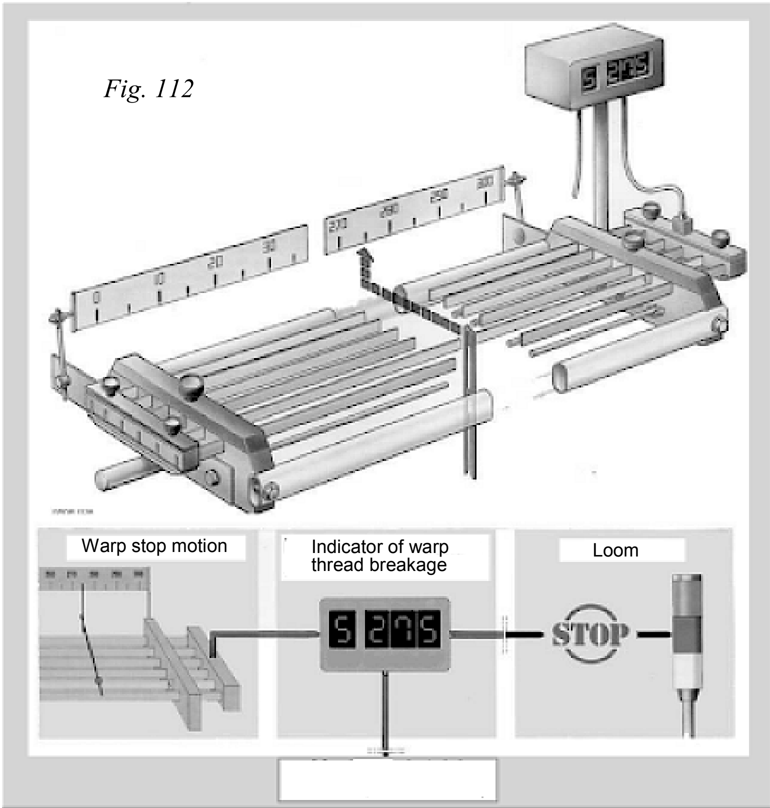
Under normal conditions the drop wire is supported by the thread and no current passes through the circuit. However when the thread breaks or loosens too much, the drop wire falls and its asymmetric form in the inside of t he upper part gets it to come into contact at the same time with the outside U shaped drop wire and with the inside drop wire. Thus the circuit is closed and a passage of current is generated which is detected by a processing station of the machine and causes the stop in the desired position (with closed shed, to facilitate the intervention of the operator on the broken thread). In the version of Fig. 111, the search for the broken thread is carried out by lateral levers which cause the sliding of the toothed bars in order to pinpoint with their movement the fallen drop wire.

Electronic warp stop motion

This is the latest solution proposed by the manufacturers of weaving machines.

The electronic warp stop motion in Fig. 112 signals, by means of a digital indicator, the contact rail and the position of the drop wire which originated the contact. In the example of Fig. 112, the drop wire is placed on the fifth contact rail at a distance of 275 cm; the measuring ribbon with its scale guides the operator directly to the breakage zone.

This solution permits not only the quick finding of the broken thread by the weaver, but allows also an automatic analysis of the warp stops through a data detection system.



To facilitate the detection of the broken ends, some manufacturers offer the possibility of installing electronic warp stop motions with luminous signaling diodes on both sides of each control rail.

The model in Fig. 113 signals by the lighting of a red light-emitting diode placed at the end of each contact rail the bar and its half on which the drop wire has fallen.

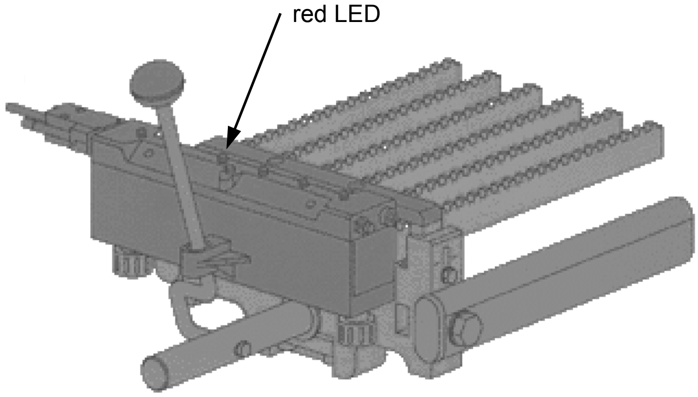


Fig. 113 – An electronic device signals by the lighting of a light-emitting diode placed at the end of each contact rail the bar and its half on which the drop wire has fallen.

Selvedges

The weaving machines need mechanisms which through the formation of sufficiently strong selvedges bind the wefts together, thus imparting to the fabric a proper appearance and solidity and preventing the breaking up of the threads on the fabric edges during the subsequent operations.
Three kinds of selvedges can be formed:

- *tucked selvedges*
- *leno selvedges*
- *fused selvedges*

Tucked selvedges

A special hooked needle driven by a cam produces, after cutting, the insertion of the protruding thread end into the subsequent shed, thus forming a stronger edge.

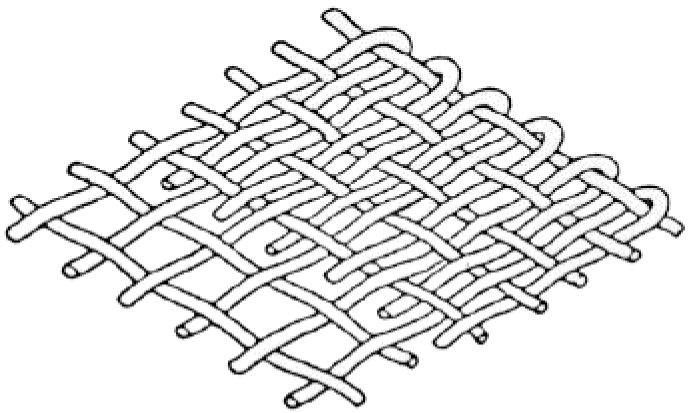
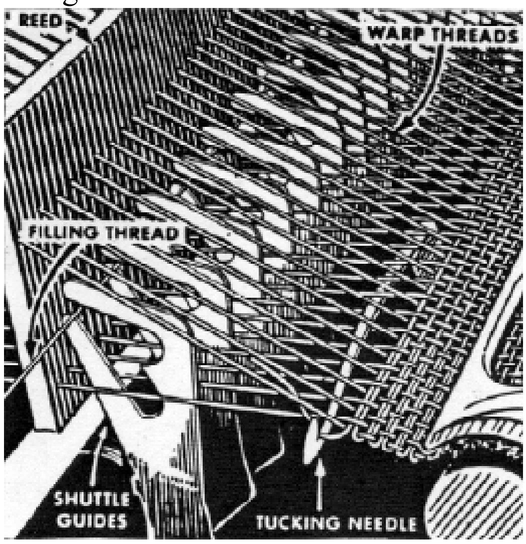


Fig. 114

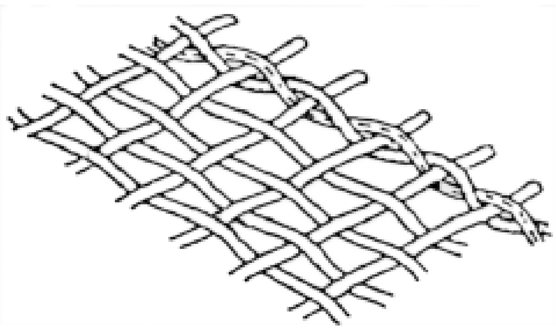


This system is generally used for light to middle weight fabrics, when weave and fabric density permit. There are also available tuck-in selvedge motions which are entirely controlled by pneumatic or mixed pneumatic and mechanical devices.

Leno selvedges

These selvedges are obtained by binding the wefts with strong additional threads working in gauze weave and by eliminating through cutting the protruding weft ends.

Fig. 115



The leno gauze system is optimally suited for heavy fabrics, blankets, wall coverings.
Fig. 116 illustrates the operation scheme of the device proposed by a manufacturer, in which device two complete leno gauze mechanisms work in combination. A leno device produces the fabric selvedge, while the other device forms the auxiliary selvedge.

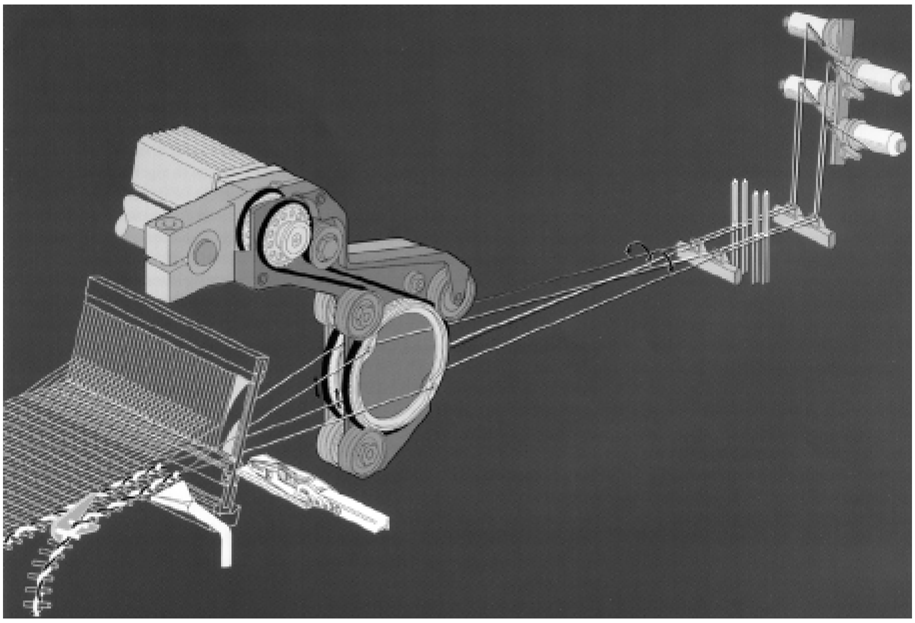


Fig. 116 – Double disk device for leno selvedges

Fused selvedges

These are obtained by pressing a hot mechanical element on the fabric edge; this method can be applied on fabrics in man-made fibres.

Devices for centre selvedges

All these three systems allow the formation also of centre or ″split″ selvedges, when several lengths of cloth are woven on the same machine.

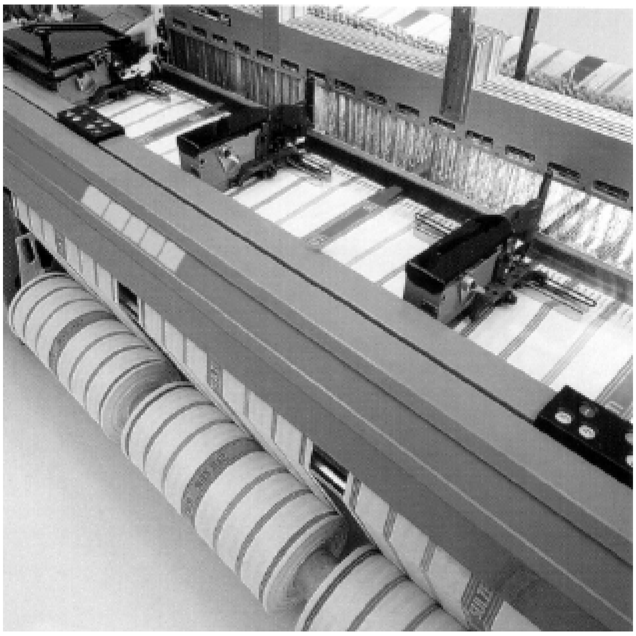


Fig. 117 – Devices for centre selvedge formation in a projectile weaving machine

Production control and analysis in the weaving rooms

The systems for production control and analysis permit to reach the following objectives:

- **collection of reliable data:** the system permits the automatic and immediate collection (in real time) of the data concerning the running of each weaving machine (stop, weft breakage, warp breakage). The result is the availability of objective and complete data which can build the base for the most appropriate choices and interventions aimed at improving the production of the weaving departments;

better use of resources: the system supplies a

- series of analytical prospects (separate for single loom, groups of looms and working department) on the production behaviour referred to various periods of time, which permit to state for each weaving machine the parameters and the optimum processing conditions. This guarantees the reduction in the number of breaks, the optimum speed and balanced machine allocations. The overall data per shift and on long periods (day, week) permit to have an efficient arrangement of the various services in the department, according to the kind of process in progress;

quick start of production for new articles: the

- data sheets for each weaving machine referred to short periods of time represent an optimal tool for the trial stage of new articles, as through the immediate indication of the results they permit a quick variation of the working parameters and consequently immediate checks and comparisons. Thus it is possible to reduce the time needed to define the working parameters and to start quickly the production of the article;

- **optimization of the setting-up:** the system can indicate in advance, on basis of the yield data recorded during the weaving process, in which moment each weaving machine will need warp beam replacement. This permits to plan in the best way the setting-up stage and to minimize the volume of warp storage;

- **easing of yield calculation:** the system stores all production data for each article processed on one or more weaving machines and permits therefore to calculate easily the industrial outputs and any comparison among the various types of looms available in the weaving department;

- **integration with a company server:** this system permits the direct transmission of the collected information to the company server. This function allows to integrate the phase of production data collection and analysis with the subsequent phases of industrial cost accounting without any manual operation of data recording or re-introduction.

Data detection

Before installing a monitoring system, it is advisable to evaluate some basic aspects to ensure a correct implementation.
One of the first basic considerations is to identify the technological period to which the machines composing the weaving department belong. There are 1st generation weaving machines which have no possibility of accessing to stop and/or production signals which are already envisaged in the

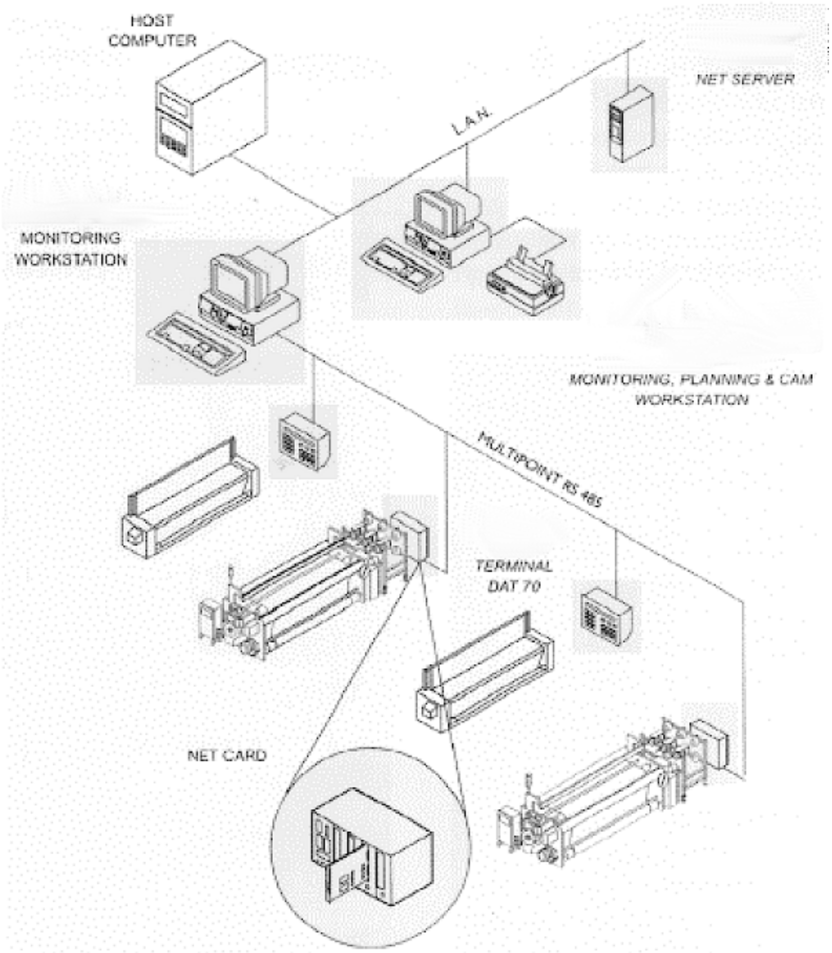


Fig. 118 – Advanced monitoring system

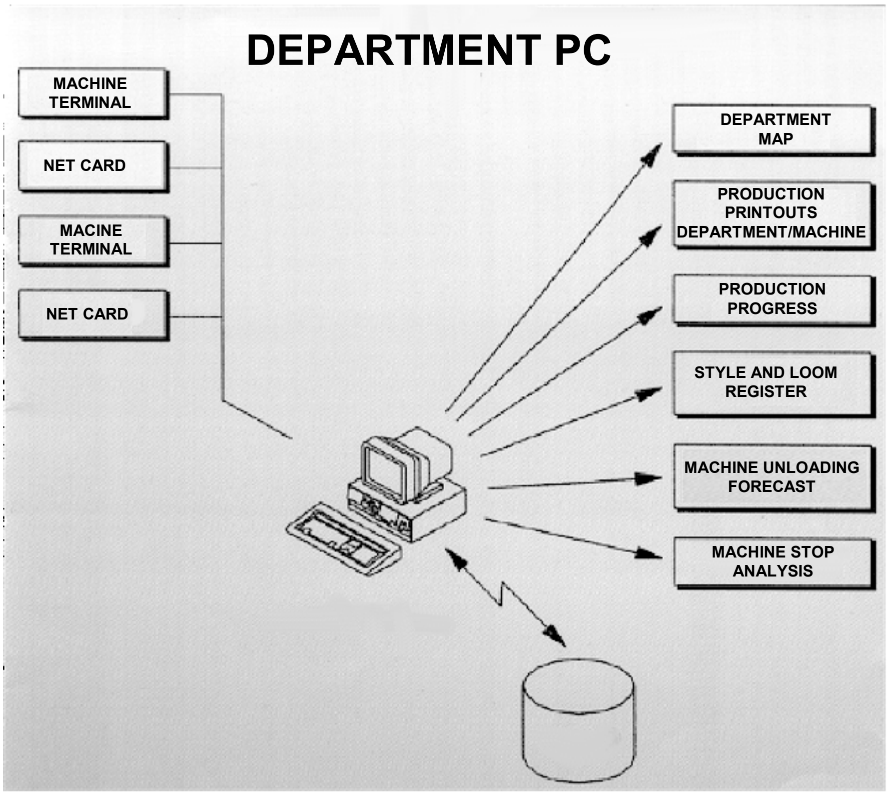


Fig. 119 – Functions of the department pc

switch-board. In th is case the machines must be equipped with suitable sensors to detect the production and to operate on the switchboard, which is often electromechanical, to obtain the warp and weft stops.
There are also 2nd generation weaving machines, which display on the switchboard, sometimes through dedicated cards, the basis signals indicating machine running and stop. On the contrary the 3rd generation weaving machines belong to a category of machines in which the dialogue between the machine and the monitoring system take place on a serial line, therefore permitting a very rich and precise exchange of information.
On the basis of the kind of machines installed in the weaving department, that is on their division into the previous 3 generations, a first decision on the configuration of the monitoring plant is possible. On 1st and 2nd generation weaving machines a data collection terminal equipped with suitable interfaces, display and keyboard has to be installed; on the contrary in the case of weaving rooms which an homogeneous base of 3rd generation machines it is sufficient to insert into the machine switchboard a microprocessor card which can interact continuously with the exchange and to control the communication on the data collection line. The most advanced monitoring installations (Fig. 118) permit to have on same line a mix of data coming from cards and terminals, thus ensuring the natural evolution of the system.

Weaving room PC

This PC receives the detected production data and represents the final point where the data are processed and stored and from where all statements expected from the system can be requested. Among the various outgoing reports displayed in Fig. 119, we wish to remind:

- **The production statement:** generally it indicates the date, the shift, the assistant in charge, the total detecting time, the machine and style codes, the production in strokes and in meters, the efficiency rates, the total stops, the weft stops, the warp stops, the stops due to the machine or to other causes.

- **The analysis statement of machine stops** which allows to learn in detail the causes of the stops in a weaving machine or in a group of machines in a certain period.

- **The statement on weaving machine unloading** which, on the basis of the collected production data, of the calculated efficiency rates and of the expected stroke number per beam, can supply the unloading forecast of each loom.

The weaving room PC has also the possibility of communicating with the company server in order to ensure an effective integration with the other company sectors.

Conclusions

We wish to conclude by affirming that these control systems, beside improving the production quality (as they permit to the operator to intervene in time by lowering the faultiness rate), supply all useful indications to establish parameters like: yarn consumption (with the possibility of organizing supplies in pre-set times and in an organized way), fabric unloading forecast (an essential factor for work planning), the optimization of the material flow, the organization of maintenance stops, etc.. In the most advanced systems it is also possible to control dobbies or working parameters through the insertion of a CAM module into the central PC (Fig. 118).

The textile CAD

CAD means **C**omputer **A**ided **D**esign, that is a project assisted by a computer. A CAD system permits to develop project functions, mainly based on the design of the item which one wants to create by using a series of tools provided by a data processing system to improve the speed and efficiency of the operations which are usually made by hand. The textile CAD is used to design fabrics and fabric variations, and to simulate quickly their final appearance through prints reproducing faithfully their colour and structure; it is used for yarn dyed, printed and Jacquard fabrics.
This system opens new ideational and planning horizons in which the choice, acquisition and manipulation of the images replace the execution of the idea. A textile CAD includes: a computer with colour monitor, a colour scanner, a colour printer and of course a series of functions which permit to design the fabrics and to store the technical data. The workstation is therefore divided into two blocks: one reserved to designing and the other to the storage. The designer can choose whether to create his design starting from the acquisition of new images or through the storage, without diminishing his own creativity which, on the contrary, can be assisted by the research and manipulation of weaves, colours, decorations, which are stored and constantly updated and extended. Alternatively, through the connection with the scanner, images and colours can be acquired, transferred to the monitor, modified and printed on paper, moreover colours not yet included in the card can be used without needing to dye the corresponding yarns. All this permits a larger creative experimentation without the cost and time limits imposed by the practical realization of the fabric. The possibility of having available a tool which quickly generates on the screen the representations of fabrics with complete and true colour effects permits to the designer to examine a number of variations extremely higher than those which will be woven later on; considering that the cost of printing is rather limited, it will be possible to study a large number of alternatives and make a choice before taking a decision. The storage, beside serving as a creative support, is of top importance for the textile mills, as it permits the analysis and the processing of countless data and to go back to the history of the product. The economic advantages of these systems are the result of a quicker preparation of the collections and of the lower interference with the production activity. However the reduction in the time needed for collection preparation is for the textile companies still more important than the saving in monetary terms, as it allows to shorten the time elapsing between the development of the new fashion ideas and the collection presentation; this way a saving of strategic time is obtained, which gives a far higher benefit than the saving of labour costs. This saving of time permits to offer a better service to the customer. Beside having the function of fabric designing, the textile CAD can process and receive information by integrating in the company’s information flow.
A further interesting fact is the drafting of the technical card for the production, which permits a rationalization of the working flow resulting from the automatic emission of the records necessary for production, raw material management, yarn requirements, recipe formulation, job order emission, planning optimization. Finally the CAD system can easily interface with CAM devices (**C**omputer **A**ided **M**anufacturing) for machine control, so that the transfer of the information necessary for fabric production becomes practically automatic and the continuous monitoring in real time is ensured, as well as the control on the whole production cycle: drawing-inn machines, card punchers, dobbies and electronic Jacquard are the various machines which a CAD device can

control directly: the controls are transmitted via floppy disk or via cable, depending on the type of interface available on the machines (Fig. 121).

Fig. 120 – CAD station

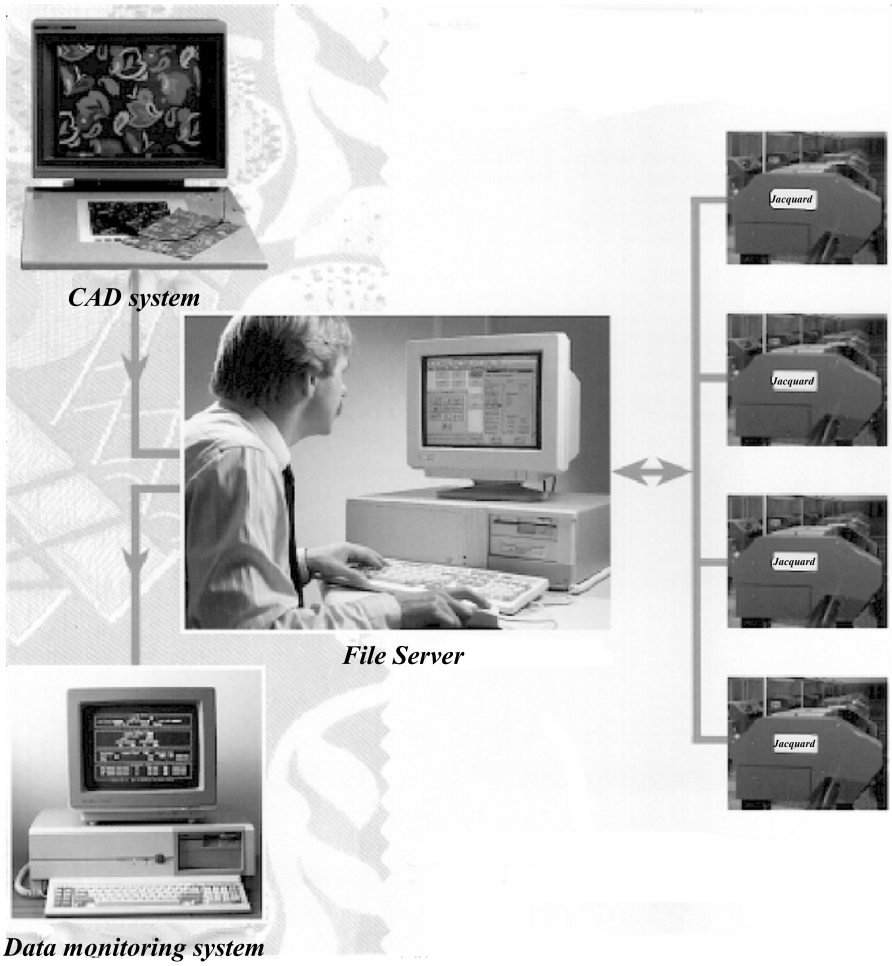


Fig. 121

Multimediality and Internet in the weaving room

In these last years we witnessed an enormous and rapid growth of the data processing technologies: the CD–ROM and INTERNET are now indispensable tools for the diffusion of the information and for order management.
The manufacturers of textile machines promptly conformed themselves to this trend and use today both data processing systems to come into contact with their customers; to this aim they manufacture weaving machines with intelligent electronics, which can ensure an increasingly advanced communication both inside (LAN) and outside the company (global communication via Internet).

Some major CD-ROM applications are:

- **The spare parts catalogue:** a software of extremely simple use thanks to a fully graphical interaction method is primarily aimed at quickly finding the spare parts which compose the main weaving machine models manufactured by the company, as well as at formulating and transmitting the orders via fax or via modem to the company's headquarters. The navigation through the web, and the data bank interrogation, are generally multilingual; therefore, after clicking on the selected language, all keys permitting the dialogue between software and user will appear in the selected language (Fig. 122), as well as all data concerning spare parts, tables and weaving machines.

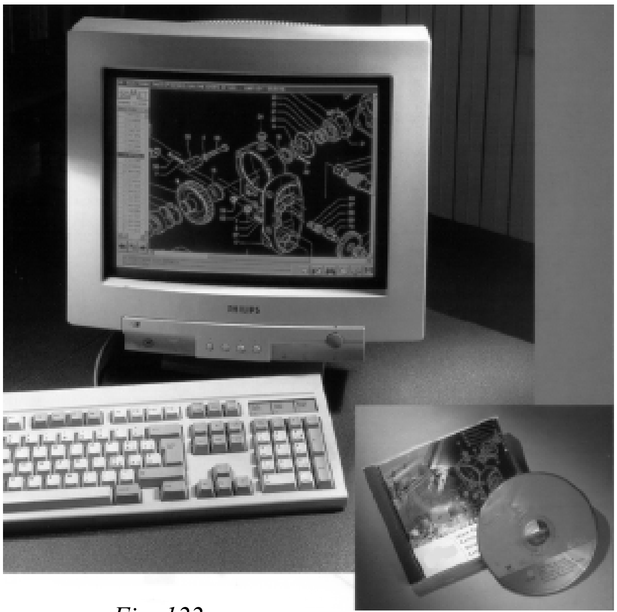


Fig. 122

- **The training of the weaving personnel:**

it permits a targeted training on the spot of the weaving personnel, in any moment and in the original language. The machine regulations and the various controls are taught in a very simple way, by means of videos, animation films and photos.

Some of the main INTERNET applications are:

- **The possibility of ordering spare parts on-line:** in this case the customer chooses the part he needs to be ordered directly by typing on the screen of the weaving machine and completes the data by inserting quantity and shipment terms. The data reach via modem the sister company and then the manufacturing head company. The order confirmation and the information on the date of delivery return to the customer in the same way. Thanks to this ″jst in time″ delivery system of the spare parts, the customer can minimize the volume of stored goods.

- **The remote diagnosis and assistance service:** through its own server, the manufacturer's Customer Service can examine the various screens of the customer's machine in order to carry out a remote diagnosis and to supply assistance directly on line.

Air conditioning installations

The stress on the yarn during the weaving process results into strains and frictions which are the more intense, the more modern and high-performing is the production machinery. To withstand the continuous wear and tear process it is therefore necessary to ensure to the fibre an optimum elasticity and a more efficient lubrication than that ensured by the batching oil. This is possible only by providing the fibrous material with a constant humidity contents. The humidity rate is an important factor also because it reduces the formation of static electricity, and needs to be adjusted according to the produced items.

Equally important is the possibility of maintaining the work environment free of dusts and suspended oil particles which are more or less injurious to the health and are continuously emitted by the running machines. On the other hand the accumulation of fibrils on the most delicate machine members, such as
the braking elements, the weft control devices, the rapiers, etc., can jeopardize their correct operation.

It is therefore essential to have an efficient conditioning plant, which can keep stable as much as possible the humidity rate and the temperature in the production room and to eliminate from the circulating air every liquid or solid pollutant.

Dust is removed from the machines by travelling clearers, while the air of the working rooms is sucked under the machines in a continuous or intermittent way and is conveyed to the conditioning stations. There the air is filtered by rotating filters and, after being humidified again, is reinserted into the room.

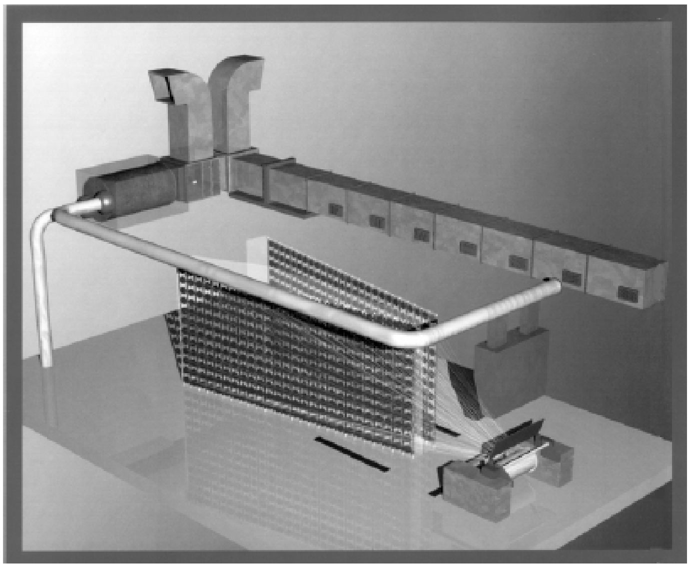


Fig. 123 – Conditioning in the warping room

The hazards in the textile industry

Every environment in which a working activity is performed, presents higher or lower accident hazards. The textile industry is characterized by the presence of a wide typology of machines and equipment, with automatic or manual transport systems connecting the various machines and departments, with dwell and storing areas; therefore the maximum attention must be paid by the operator, who has to comply scrupulously with the procedures and the active and passive safety systems with which modern machines are largely equipped. Often the distraction or the excess of ″confidence″ with the machines are the occasions for accident hazards. The hazards can also be increased by the environmental conditions of certain departments, by the kind of organization and by the existing work paces.

The risks of damages and diseases for the human organism in the textile industry can have following causes:

1) **unhealthy microclimate:** this is the case in particularly of the dye-houses, the environment of which is characterized by a high humidity level and by the presence of more or less harmful or irritant fumes, which are often associated with high temperatures and with an insufficient change of air. Also in certain spinning departments the necessary humidity rate, often combined with a certain presence of dust in the air, can result in breathing problems. The fibre dust which is emitted mostly when processing vegetal fibres can cause, in the more sensible subjects, an irritation of the bronchus, associated with a continuous production of mucus, and originate with the time chronic diseases as pharyngitis, tracheitis and bronchitis;

2) **noise:** noise represents in various departments and above all in weaving mills a problem of primary importance, especially if there is not enough room available and no adequate soundproofing intervention on the machine and on the rooms have been carried out. In such cases the alternative is the use of individual safety devices. A high noise level can entail a reduction in the functions and other secondary collateral effects;

3) illumination, working position, precision, rhythm, repetitiveness, turnover system: various tasks require a considerable stress on the sight, or need body postures which have to be maintained long time, or require much attention, rapidity of execution, repetitiveness at very short intervals, temporary adaptations which can be the source of various pathologies both at physical and at psychical
level.

Noise in the weaving rooms

In the textile industry, the noise problem in the various working departments is a cause of serious concern. The highest noise levels are to be found in the weaving rooms, where the operators are exposed to levels of 94 to 100 dBa. The needs of having the possibility to control fabric quality prevent any casing or partial shielding of the weaving machines, it is however possibile to correct the acoustics of the working room. The mostly used materials are:

1. **glass wool baffles put in a glass fabric envelope and hang up on the ceiling;**
2. **glass fibre panels with an interspace between panel and adjoining wall;**

These measures, unfortunately, are not very effective, so that the personnel is anyway compelled to use the devices for individual protection. In fact these measures reduce the noise level only by 1 to 1,5 dBa between the weaving machines and by 2 to 3 dBa between the beams and in the department passageways. The above mentioned modest results, typical of the weaving rooms, are due to the preponderance of the direct waves (coming from the noise sources) over the waves which are reflected by other bodies and to the distance of the sound absorbent material from the noise sources. The devices for individual protection which the workers have to use against noise are of various types and give different results with the variation of the frequency. There are devices which protect better at high frequency values (1000-8000 Hz) and others which are more efficient at low to medium frequency 125-1000 Hz).

Table 1 shows the average performance of various types of protection in respect to the different frequency values.

	Frequence Hz						
Type of ear protection	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Cotton staple	4	5	5	9	19	17	14
Shaped inserts	6	6	7	9	21	27	13
Selectone K insert	7	8	6	10	21	31	28
Insert of cotton and wax	8	10	12	16	27	32	31
Feather wool	6	8	11	15	19	26	35
E:A:R: polymer foam inserts	26	27	29	30	33	44	44
Earplug V-51 R inserts	20	19	19	22	27	29	30
Preformed silicone inserts	18	17	23	21	30	42	39
Malleable inserts	24	25	26	26	35	42	40
Shaped inserts in resilient material	27	27	28	30	35	45	40
Casings (foam seal)	8	14	23	31	32	36	31
Casings (fluid seal)	20	18	23	31	35	38	31
Casings (liquid seal)	19	24	32	41	38	42	32
Anti-noise helmets	15	20	24	33	40	53	50

Table 1

Noise origin and problems in weaving machines

Noise is caused by the vibration of the mechanical parts of the machine. These parts can be either in motion (various kinematic motions) or standing (structural parts, boxes, casings). The moving parts are the main origin of vibrations, which are then transmitted to the other parts of the machine. The vibrations are the higher, the more intense are the load variations to which the moving elements are submitted: sley, heald frames, weft inserting elements.

These movements are alternative motions and have rather high operation frequency levels; as such motions generate the maximum load variation values on the involved mechanical elements, it is easily understandable that the resulting vibrations and the pertaining noise, can attain very high values.

The noise of a machine depends therefore to a very large extent on the operating speed but also on the machine equipment viz. on its composition, as this entails a different quantity and typology of the mechanical units, each with different vibration mode. For this reason the weaving machine manufacturers are following two well known basic lines in their production:

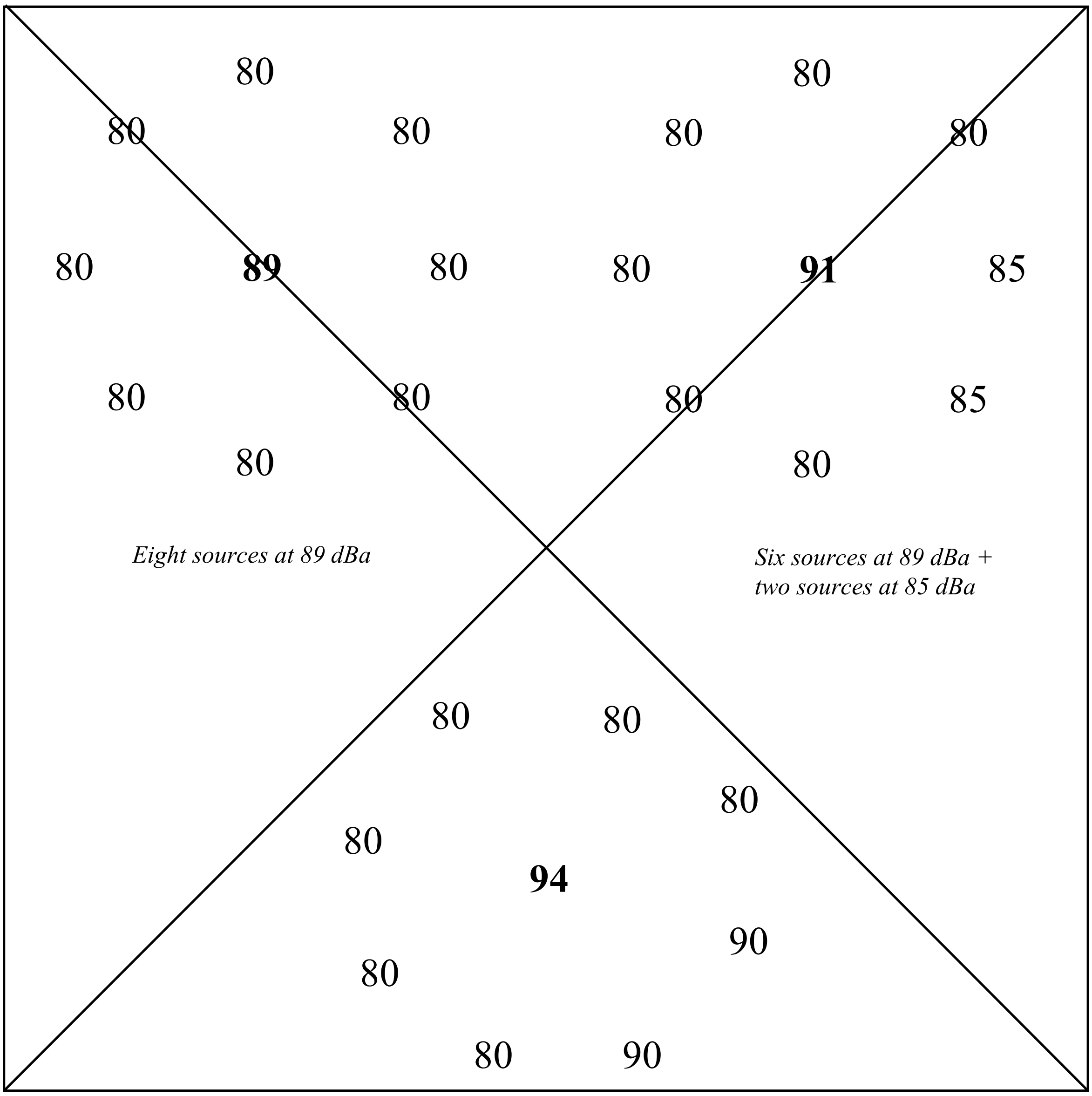
1. **noise reduction already at the designing stage;**

2. **reduction of the noise reaching the operator by means of physical barriers between the noise sources and the subject (casings).**

A further possibility could be, as previously indicated, the modification of the mill acoustics.

In fact, although a great deal of progress has been accomplished to reduce noise in the weaving rooms, there is still a long way to go.
We need only to consider that the noise emitted by a modern rapier machine is about 90 dBa (maximum level of acoustic pressure in 8 hours per day for a single person at 1 meter distance from the machine surface) when the machine turns at 500 strokes per minute without screenings, viz. the same noise level emitted by an old shuttle loom running at 180-200 strokes/minute.
Thanks to the technological development, the weaving speed in the last 20 years has more than doubled, however without increasing the level of acoustic pressure.
The attention which most of the industrial countries give today to the issue of environment pollution is more than justified. The noise is not only annoying, but can be harmful to health and at the end increase the social costs.
The EEC guideline Machines 89/392 draws the attention to this problem and invites the manufacturers to design machines *in such a way, that the risks due to noise emission are reduced to a minimum, in consideration of the technical progress and of the technical means available to reduce the emissions at their source.*
This guideline obliges the manufacturers to declare the noise levels emitted by their machines. The noise evaluation of a single weaving machine is anyway not sufficient; in the textile mills dozens, not to say hundreds, work simultaneously in one and the same weaving room and the sound level increases in proportion to the number of looms, even exceeding the threshold of 90 dBa indicated by the present Italian legislation.

The graphics here below show the noise increase in relation to the variation in the intensity of the sound produced by a certain number of sources positioned side by side. You can note that, with 8 noise sources at 89 dBa, the noise level on a central measurement point is equal to 89 dBa; in the case for instance of two noise sources, by increasing the noise level of each source by 5 dBa, we get a variation in the central point of 2 dBa.
In the third graphic, if we bring the same noise sources to 90 dBa, we get a central point at a level of 94 dBa. This variation in the value of the central detection point in relation to the change of the sound level of the two noise sources follows a logarithmic trend.



Six sources at 80 dBa + two sources at 90 dBa

Fabric defects and problems of machine regulation

The finished fabrics can show various kind of faults which can be ascribed to the operations which follow one another till the realization of the finished fabric. The most common defects which appear in more or less extended areas of the fabric are:

- knot;
- crease, mark;
- abrasion or hole;
- tear;
- stain;
- dirt, contamination;
- moirè = presence of vawy areas in periodical sequence, reflecting the light and due to a different compression of weft or also of warp.
- grain = presence of designs with streaked and sinuous lines.

The most common fabric defects due to warp are:

- Faulty thread = a thread or pieces of thread which are coarse, fine, irregular owing to higher or lower twist or to other twist direction, of different colour, with two or three ends;
- missing thread = a thread or pieces of ground or effect threads which are missing in the fabric weave;
- tight/slack thread = a thread or pieces of thread which are tighter or slacker than the other pieces/threads;
- incorrectly woven yarn = a thread which in some parts only of the fabric is not interlaced in the standard way
- broken warp = small pieces of cut or missing warp thread
- reversed thread = crossed, exchanged threads or thread pieces;
- warp stripes = one or more faulty threads giving rise to zones of different aspect; it can be due to scraping or rubbing from members of production machines or to inaccurate reeding;

The most common fabric defects due to weft are:

- Faulty weft = a weft or pieces of weft which are coarse, fine, irregular (slubs, etc.), twisted, reversed, with different twist, of different colour, double weft;
- missing weft = weft or pieces of weft missing in the fabric weave;
- tight/slack weft = a weft or pieces of weft which are tighter or slacker than the other pieces/wefts;
- incorrectly woven weft = a weft which in some parts only of the fabric is not interlaced in the standard way;
- cut wefts = short pieces of cut wefts;
- weft bars (starting marks) = visual light/dark effect in weft direction due to higher or lower weft density caused by the weaving machine.

The quality control on the fabrics is carried out on a special inspecting machine, equipped with special lamps which facilitate the defect detection by the operator, marks them with labels of different colours according to the fault type and importance.

Depending on the number of faults and on their importance, the fabric pieces can be classified as standard (in respect to quality specifications) or can be subjected to a more or less serious degrading with consequent compensations to the customers or with the sale of the fabric at a reduced price.

Various defects can arise during the stages of weaving preparation (warping, sizing, threading-in into the heddles and into the reed) as well as during weaving itself. It is therefore important to regulate accurately the various devices of the weaving machine and to understand how to act in case of anomalous operating situations which create defects and/or reduce weaving efficiency.
Let us see in the following which practical effects some of the most common regulations might have.

Warp tension

The warp must be under tension to permit weft insertion and fabric construction.
The increase in the tension avoids stressing heavily the yarns during the reed beat-up, reduces their sticking together during shedding especially when weaving yarns with poor elasticity and with low hairiness, facilitates the separation of the interlaced or glued yarns and the passage of the knots through the reed. The tension might however increase the tensile stress on the warp threads and consequently lead to a higher number of broken ends. On the other hand the reduction in the tension results into a lower yarn breakage rate and also into a lower friction of the threads against the heald frames. In certain cases it could cause however difficulties in obtaining the desired weft density owing to the less effective stroke.

Position of the back rest roller

- horizontal regulation: it is suggested to move the back rest roller away from the harness to reduce the elongation of the single threads, particularly when using yarn with low elastic recovery or when weaving with a high number of heald frames. The back rest roller can be however brought near to the harness when you want to increase the elongation of the single yarns with the purpose of reducing the sticking of the threads together; at the same time an adequate distance from the warp stop motion should be maintained in order to favour the lining up of the threads with the respective drop wires and to facilitate the repair operations;
- vertical regulation: with back rest roller positioned in the centre to get a symmetric shed and thus to reduce the stress on the threads during shed opening (normal condition); with back rest roller moved upwards to loosen the threads of the upper shed and to favour the insertion of the wefts in very dense fabrics; with back rest roller moved downwards to reduce the stress on the release springs of the heald frames in the Jacquard machines or when weaving with the warp effect of greatly unbalanced weaves turned upside down;
- locking position: the locking of the back rest roller is carried out when stiff warp yarns are used in order to reduce the oscillations, or when snarls arise owing to the twist of the beam threads;
- free rotation: the back rest roller rotates when delicate warps, elastic warps or warps with high elongation are used or when only few heald frames are in motion (limited oscillations).

Warp stop motion

The selection of the type of drop wire, of the weight and density of each contact rail must be made with great care on basis of the yarn count and composition, following the indication of the manufacturers. The responsiveness of the warp stop motion can be increased by reducing the drop height of the drop wires towards the contact rail, in case of threads which are prone to get entangled or which show very difference counts or twists. This responsiveness can be reduced in case of loose threads or false stops.

Shedding

The centering of the shed towards the weft insertion tool used plays an important role, to avoid abrasion risks, weave defects, thread cutting, selvedge trimming and other faults. An increase in the shed dimension reduces the possibility of mistakes and thread breakage caused by their sticking together, whereas a decrease in the shed dimension reduces the stress onthe threads. Sometimes it can be necessary to offset the heald frames to favour the separation of the threads or to avoid placing threads with too different tension close to each other.

Timing of the dobby

It might be convenient to advance the shed closing time of the dobby when using very dense and hairy warps, to improve the clearness of the shed; this way the possibility of producing loose wefts after the opening of the pulling rapier is reduced and the possibility of blocking the wefts during the stroke is increased. The closing of the shed is on the contrary delayed to obtain a better extension of the weft and to facilitate its insertion.

Take-up coatings

The take-up coating plays an important role to prevent fabric gliding during its taking-down, which would cause unavoidably streakiness. In general the friction coefficient should grow with the increasing of the warp tension. The maximum adhesion of the fabric is obtained using emery cloth coatings, but sometimes this kind of coating can result in abrasion spots on delicate fabrics. In these cases surfaces coated with rough or smooth rubber, or with resin are used.

Anti-streakiness cycles

The modern machines equipped with electrically connected electronic warp let-off and cloth take-up motions which are managed by the microprocessor system of the controller permit to carry out maintenance cycles aimed at avoiding the formation of stripes (continuous stripes and loom starting marks) after machine stops, while taking into account, at loom re-starting, the different reed beat-up speed in respect to the running speed, the plastic deformations of the threads and of the fabric, as well as possible displacements of the fabric formation edge during the stop. To avoid different initial beat-up conditions, it is also possible to carry out idle strokes.

Other interventions

Many other regulations are possible: on weft feeding and braking mechanisms, on selvedge formation devices, on temples, on weft cutting, on insertion mechanisms used. The fact of being in a position to produce the best suited regulations and corrections contributes in a decisive way to the improvement of the fabric quality and of the weaving efficiency.

Cost accounting

There is not just only one procedure which permits to standardize the way to follow to determine the cost of an article, as every weaving mill works out a procedure of its own which allows to quantify the cost of the article under manufacture. The following proposal does not indicate therefore a general way of proceeding, but means just to be an example for this calculation.
A weaving mill equipped with negative rapier weaving machines produces a cloth with following technical features:

- Warp yarn count: Nec 30/1
- Weft yarn count: Nec 30/1
- Weight per sq. m.: 130 g (50% warp / 50%weft)
- Weaving wastes: 5%
- Grey fabric width: 248 cm (selvedges excluded)
- Warp and weft shrinkage: 10% (± 1%)
- Processing yield: 88%
- Number of machines: 50
- Insertion speed: 350 strokes/minute
- Working days per month (average): 23
- Working months: 11
- Shifts per day: 4 of 6 hours each
- Yarn cost (Nec 30/1): lire 8,000/Kg

Beside above mentioned technical data, the weaving mill knows some plant management expenses, which are fixed expenses resulting from the projection of the expenses of previous years and from the forecasts for the works in progress or to be carried out nextly:

- Personnel expenses: Lire 1,120.000.000 (20 production workers)
- Machinery depreciation: Lire 500,000.000 (for 5 years)
- Energy and heating expenses: Lire 180,000.000
- Building maintenance: Lire 50,000.000
- Plant adjustment : Lire 120,000.000
- Other expenses: Lire 340,000.000

Let us calculate the cost per stroke which is necessary to depreciate the annual expenses. By cost per stroke we mean the multiplier in lire which permits to calculate the cost per meter of our product. To facilitate the calculation, we consider it as already multiplied by 100 in order to obtain values per meter.

First of all we calculate the density per centimeter of the fabric elements on the basis of the weight per sq. m. :

130 g (weight/sq. m. of the fabric) / 2 (the elements are each 50%) = 65 g (weight of warp and weft)
Nec = 0.59 x L / W, therefore L = Nec x W / 0.59 and, by replacing our values
L = 30 x 65 / 0.59 = 3,305 m (real warp or weft length in sq. m.)
3,305 – 10% (shrinkage) = 2,974.57 (apparent length)
2,974.57 / 100 (centimeters in one meter) = 29.74 →30 (density per centimeter)

As both elements participate each with 50% to the fabric, the density we calculated with this procedure applies also to the weft. We calculate then the annual production in meters of the weaving mill:

350 (machine strokes/minute) x 88/100 (R%) = 308 (real speed)
308 x 60 (minutes in one hour) x 24 (total working hours of the shifts per day) x 50 (weaving machines) = 22,176,000 (strokes per day of the department)
22,176,000 / 30 (strokes per cm) x 100 (cm in one m) = 7,392 m (daily production in meter)
7,392 x 23 (working days per month) x 11 (working months per year) = 1,870,176 (meters produced in one year).

Now we need to calculate the expenses which we have to bear in one year. This datum results from the sum of the expenses:

1,120,000,000 + 500,000,000 + 180,000,000 + 50,000,000 + 120,000,000 + 340,000,000 = 2,310,000,000 (total expense)

If we divide such expense by the meters produced, we obtain the expense incidence on each meter:

2,310,000,000 / 1,870,176 = 1,235.17 (mark-up per meter to depreciate the expenses)

To this figure we have to add the cost of raw materials:

130 g (weight per sq. m. of the fabric) x 2.48 (finished width in m) = 322.4 (weight per linear meter)
322.4 + 5% (weaving waste) = 339.36 (weight of the raw material)

Let us calculate the cost of cotton:

339.36 x 8,000 / 1,000 = 2,714.88 (cost per meter of the raw material)

The total cost to divide on each meter is:

1,235.17 + 2,714.88 = 3,950.05 → 3,950

Finally, the cost per stroke results from the ratio between the born expenses and the density per centimeter of the article:

3,950 / 30 (strokes per centimeter) = 131.6 → 132 (cost per stroke)

Obviously this value permits only to recover the expenses, and every mark-up permits to get a profit at the end of the year; if the mark-up is between 132 and 150, we obtain:

150 x 30 = 4,500 (price per meter of the fabric)
4,500 x 1,870,176 (meters produced in one year) = 8,415,792,000 (annual proceeds)
(339.36 / 1,000) x 1,870,176 x 8,000 = 5,077,303,419 (annual expense for raw materials)
5,077,303,419 + 2,310,000,000 = 7,308,303,419 (total expenses born in one year)
8,415,792,000 – 7,308,303,419 = 1,107,488,581 (profits in one year)

Of course this calculation is only indicative of the various expenses which come into play in practice and does not consider at all some processes, as e.g. warping, nor the various rebates or special prices which are granted to regular customers or against big orders. Moreover the calculation assumes the production of only one and the same article on 50 weaving machines, although we know that in reality the situation is quite different with many producers; the calculation is anyway indicative of the mechanisms which regulate the price determination for the finished product.