Chapter 2

Literature Review

2 Literature Review

2.1 General

Warping has been defined as "Warping comprises winding parts of the warp yarns, normally from bobbins, on a warping beam, whereby sequential parts are wound next to each other until the full weaving width is covered. The warping beam is then normally in a next step of warp preparation used for beaming." Whereas beaming is defined as "Beaming comprises winding the full width of the warp yarns in a single winding operation on the weaving beam (i.e. the beam which is to be placed on the loom). The warp yarns can be wound from a creel or a warping beam". (1)

A weaver's beam may contain several thousands of warp yarn. These warp yarns are wound parallel over the width of the reed space. Winding of these yarns at a time on to a beam would require a creel which can accommodate these many bobbins. Practically it is very difficult to manage a huge creel which can accommodate several thousands of warp yarns (2). So it is normal to use an intermediate solution by taking several hundreds of yarns from creel and wind them on an intermediate beam called warper's beam. Alternatively, several sections of the threads are wound initially on, one side cone shaped, drum and then transfer all threads on to a beam. From above there are mainly two categories of carrying out the process (3) *viz.*:

i. Direct warping
ii. Indirect or Sectional warping.

There are few other methods also like ball warping – for preparing ropes for indigo dyeing, sample warper, warp knitting beams etc. These are specialized methods and are used for the specific products and / or application (4, 5). So, in this chapter the focus will be on two main methods only.

The history of warping is as old as the history of weaving. Warping process has always been an important part of the weaving preparatory processes. It was carried out manually with wooden frames in very early days. Gradually the mechanized system came in to place and later on there was development of sectional warping. Most of the published literature in books and journals discuss about one or the other process parameters. Not much content is available with reference to design aspects of both types of warping systems. In the present literature review work, some of the relevant research work published will be cited. Also included will be the survey of patents filed so far with reference to the design modifications.

2.2 Effect of Process Control Parameters

2.2.1 Quality of Beam

As mentioned, warping is an intermediate process of converting a single package to multi-end beam. Though the process is of simple conversion, it is considered to be very essential because any flaw in the process will result as a defect in later on stage. Many papers have been published covering the effect of various process parameters on quality of beam and on later on processes. Some will be discussed here.

Dyer et.al., in 1952, studied effect (6) of various types of tensioner and concluded that compensating tensioners are not effective for use. Instead simple type of tensioner will give better result if the angle of wrap has been calculated properly for given warp yarn. This provide uniformity of thread tension across the whole width of the threads.

According to Renner (7), ever greater fluctuation of fashion trends, the wide variety in constantly smaller orders and the demand for shorter production times have affected warp preparation in the sense that it has accentuated the advantage of sectional warping over beam warping, as sectional warping produces warps of good quality. The sectional warping machines such as are available today and the automatic winder on which packages with optimum run-off characteristics are formed, meet these requirement.

As per Renner, the thread tensioners used on the creels of modern sectional warpers must satisfy some specifications. They must not accentuate any thread tension variations originating from the package. In this respect roller thread tensioners, such as on the Benninger, appear to be most suitable. Compared with standard pressure tensioners with tensioning plates or rods, the roller tensioners offer the advantage of being able to equalize tension variations in the thread balloon without creating higher tension when a knot passes through and without becoming contaminated. In this design it is very easy to reset when a lot is changed, in that presetting of all tensioners is undertaken centrally by motor drive. The thread tensioners must be continuously and individually adjustable in accordance with their position in the creel.

The tension problems outlined been largely solved by direct adjustment facilities on the thread tensioner itself. For instance, on the Benninger sectional warper monitoring takes place very close to the point at which the section runs onto the warping cylinder. When any change in basic value is noticed, the computer is able to take action directly on the thread tensioner as it knows the number of ends in the warp section and the preselected target tension. On the Hacoba machine the thread tension is checked by an electronic feeler. The preselected thread force does not vary with changing take-off speeds, since the thread tension is adjusted automatically by the feeler. In the present state of the art it is not yet possible to monitor and control the tension of each end individually.

Renner has further deliberated upon two types of sectional warping machines:

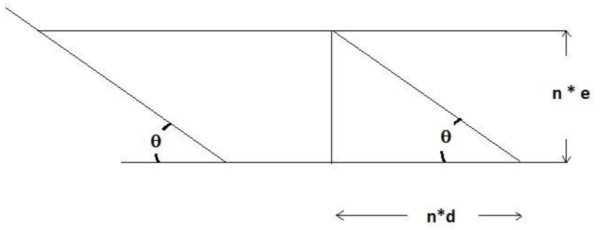
(i) Sectional warpers with variable cone height

(ii) Sectional warpers with fixed cone height.

Today most of the newer generation machines are with fixed cone height and all machinery manufacturers offer machines with a particular value of cone height depending on the application. But way back in 80s it was just introduced.

During sectional warping the lateral displacement of the sections made by traversing the warping headstock is by an increment d in mm and if e is the mean thickness in mm of a section and θ is half the cone angle. Then,

$$tan\theta = \frac{n*e}{n*d} = \frac{e}{d}\ , \quad \text{so,} \quad d = \frac{e}{\tan\theta}$$



Where,

n = no. of cylinder revolution

d = carriage traverse per cylinder revolution (mm)

e = mean section thickness (mm)

θ = half the cone angle (deg)

If faulty wind on in the first section is to be avoided then it is absolutely essential to ensure that the increment d and the angle θ are determined very carefully and precisely. The problem is that it is very difficult to determine the mean section thickness e in advance, i. e. before warping commences. It is dependent on a number of factors, e. g. on the material, the yarn fineness, the surface structure, the twist and the tension. One must be aware that such equations are not usually found much in literature which take all these factors into account. The best method of approximation is to perform a preliminary trial on a measuring roller positioned behind the warping reed, taking into account all these factors with the exception of tension. However there are two methods of forming a cone on the warping cylinder.

In the first method the cone is built up by a system of steeply angled sections. As the factor e is a known value. In this form of build, the values of d and θ can be established with adequate precision. The value θ is variable and the lowest possible value is adopted to avoid sloughing-off of the warp section, but yet the value must be great enough to allow the section height produced by the required warp length to be built up. The disadvantage of this type of machine is that part of the warp sheet coming into contact with the cone is not circular but is in the form of a polygon of smaller circumference within the circle. This portion of the section is therefore of shorter length than the sections subsequently wound.

In the other type of construction, a cone of fixed dimensions was built into the warping cylinder. This provided a firm basis for the threads. As the factor θ is not now variable, however, at the start of sectional warping, the factor e is not yet known and d remains the sole variable factor. To ensure an adequate level of precision, then the value assumed by d must be any desired value and be continuously variable.

Considering the possibilities available through electronics, then fixed cone angle type of machine is to be preferred to that with variable cone angle. So if it is known, the precise value of increment is entered into the microprocessor before warping commences. Right at the start of warping, the machine is made to make two measurements of cylinder diameter, at section builds of 2 and 8 mm. As the computer has the value of number of cylinder revolutions occurring between the two measurements, it is able to determine the mean section thickness e that has been built up. From the value of the angle which is also known, it can now calculate the precise increment d. This value is now adopted definitively and maintained to the end of the warp with a precision of 0.001 mm. To maintain consistent warping conditions, subsequent sections are wound- on with the same increment.

An equalizing roller subsequently exerts pressure on the section being built up in order to ensure that the actual height of the section corresponds at all times with the target value corresponding to the number of revolutions. The combined action of these two devices ensures that the built throughout the warp is perfectly cylindrical.

2.2.2 Objectives for Designing Beam for Direct Warper

Scholze has stressed much on the quality of warp beam (8) and has highlighted importance of selecting best possible warp beams to achieve higher and better output from a warping machine. The main points to be checked about quality of beam are smoothness and finish of the flanges, about the type of adapters, beam driving means in terms of fixing it on either warping machine or afterwards on sizing and loom. The aspects are to be considered separately for beams to be used for direct and indirect warping. Also beams to be used for spun and filament will have different quality parameters.

The varying characteristics of the fibers being processed call for appropriate warper beam designs. The chosen material for the beam must be such that the limited elastic and plastic deformation can be adhered to at the given loads. This is particularly the case with warper beam tubes and flanges. In order to prevent uneven tensions being caused by the unevenness in warper beam heights, tube heights and flange axial thrust should be maintained up to tenths of a millimeter. Only warp beam flanges with smooth outer surfaces should be used. This also helps to produce warps which are free of fluff. Safety is also considerably enhanced.

The demand for automatic feeding is met by conically serrated drive couplings, where the drive pivot has to be aligned with the drive holes, which again holds good for the conventional warper beams with pivot bearing. This conical gearing can of course also be used for filament yarn beams. The conical gearing enables the warp beam to be centered, so that the tolerance from the center of the machine to that of the warper beam is equivalent to zero. The gearing, mechanically worked, is used for centering and for frictional connection.

Unwinding of the warper beams in the supply creel of the sizing machine is also best effected, for instance, with conically serrated drive couplings to ensure optimum tension adjustments with a very accurate, smooth beam motion. Again it is very important that this is achieved without any lever arm effect. The lever arm effect is present both on warper beams with gudgeons as well as from the beam to the warping machine itself as well as in the sizing machine supply creel.

Additional tensioning grooves on the outer edge of the flange have the disadvantage that there is a danger of the edge being stretched when it is rolled on the floor. If an additional tensioning groove is nonetheless desired, it should be made of non-rusting material and the band insert preshrunk to prevent rust and stretching during transport as well as to increase operating safety and prevent accidents when handling these warper beams. To ensure careful handling of the pressure roller and to increase productivity, it is advisable to equip the warper beam tube with a cloth covering, or to treat the surface in such a way so as to ensure that the warp ends have better adherence. When processing cotton and rayon spun fiber yarns, the fabric should be fixed to the tube with a moisture-proof adhesive.

When warping up, the end threads are tied into plaits, which run into the warp beam over the pressure roller and are then secured. These plaits have to be cut off, to prevent uneven running and thus vibrations on the machine. Using the method described above, the thread layers do not become uniform until after a number of revolutions, when the warp beam tube is covered with yarn sheet, it is no longer necessary to work with plaits.

It should be possible to dismantle the elements of the warper or warp beam such as drive couplings, flange and tube in order to reduce freight costs and ensure that the parts are interchangeable. In this case the warper beam must be re-balanced, in order to avoid heavy vibrations, premature wear of the warper and accidents on the machine, as well as to obtain optimum machine, efficiency. The residual unbalance should not exceed 8.1cN per flange on warper beams with flange diameters up to 800 mm, and 10.1cN per flange on flange diameters up to 1000 mm.

When designing warper beams, advantage should be taken of the more favorable moment of inertia offered by lighter beams with accurately reproduced dimensions, resulting in more rapid starting and braking. A good warp quality is only possible if the tube diameter is not less than 250 mm. The internal and external transport of warper beams and of yarn carriers in general should be organized in such a way that they cannot get damaged.

If all these factors are taken into consideration, it should be possible to obtain uniform yarn tension in the warper beam supply creel. The warp tension should be monitored from its entry into the sizing machine in order to improve the running properties of the warp.

2.2.3 Objectives for Designing Beam for Sectional Warper

As far as the dimensions of the sectional warp beams are concerned, specific tolerances should be adhered to and should not exceed:

- ±0.2 mm in the case of the tube diameter
- 0.3 mm for the conicity of the tube
- 0.4 mm for the clear width and
- 0.3 mm in the case of the flange thickness.

Deformation –both elastic and plastic, of the two flanges should be roughly the same. As far as the working of spun and filament yarns is concerned there will not be much of the difference in the design of the beam. When deciding on the construction and choice of materials, the requirements of the various kinds of synthetic yarns should be defined with respect to the permissible limits for flange and tube deformations, paying attention to an equivalent amount of deformation both of flanges and tube. The combination of strong tube and soft flanges or thin, excessively flexible tube and rigid, unduly stable flanges is not advisable. Proper dimensioning and selection of the most suitable steel quality is important. The tube diameter should be such that the tube is not likely to sag under its own weight and when loaded with warp. Tying holes should be avoided as far as possible, as they weaken the tube and encourages sagging. Depending on the application, steel tubes, welded and high-precision steel tubes can be used. A certain wall thickness should be assured around the thread area.

More attention will of course be required if the beam is be mounted on a wider loom because the tube of the wider width loom may not be able to withstand very high loads which are centered. Some times to overcome the problem, half beams are used meaning the entire width is split in to two parts provided by warp coming from two similar beams. As the let off mechanism of the loom is common, greater care is required to prepare such beams. Typical example can be multi width of projectile looms.

2.2.4 Yarn Stresses on a Beam

In his paper Hubner has discussed about the effect of increase in loads on beam by increasing the flange diameter. He also mentioned that processing of filament yarn also increases the load on beam. He has devised (9) a pressure and material dependent density factor k which depends on fibre density and winding density. Based on all above parameters it will be possible to arrive at an optimum value of beam flange diameter for a given type of yarn without overloading the entire system.

Lange and Weinsdorfer have analyzed (10) stresses on yarn during warping and beaming. They have mentioned about impact of increased speed of looms and its effect on requirements out of preparatory processes specifically warping process. In the paper an extensive research project has been cited covering the yarn unwinding characteristics from the cross wound package in the creel, the action of different thread tensioners in current use in creels and thread tension variations between different package positions in a warping creel and a beaming creel. The testing was done using thread tension meter operating at high frequency which permits very short thread tension peaks to be recorded. The results may lead to an optimization of various parameters which in turn will reflect in reduced defect level at fabric stage particularly warp stripes problem. One of the main reasons for warp stripes problem is irregular thread tension which mainly arise at the warping stage.

In his papers, Dorgham (11, 12) has extensively studied effect of yarn count, thread tension in creel, warping speed, different yarn materials and different distance from creel to drum on a Benninger sectional warping machine. One of the outcome of the study was that the tensile strength of yarn reduced in all cases with increase in the distance between the creel and the drum with not much effect on elongation. The reduction in strength was more significant in case of spun than in case of filament yarn packages.

Fernando and Kuruppu (13) carried out an analysis of of tension variation in creel used on a sectional warping machine. They also developed mathematical model of yarn tension variation within the creel. The experiment suggested that the yarn tension increases from bobbin exit point to its exit from the creel.

2.2.5 Problems of Running Smaller Lots

With increasing demands from fashion and retail industry, fast moving life cycle of textile products, it has become now necessary to adopt quick response system so as to reduce lead time to manufacture. Also running smaller lots puts lot of pressure on productivity of the entire textile production chain, mills normally settle down for mass production of fewer varieties. In their papers, Goddard (14, 15) et.al. have described the problem of running smaller length in light of weaving preparatory processes. It has been mentioned categorically that two systems of warping differ markedly in their method of producing intermediate beams. They have shown that beyond 20,000 m length the time required to warp is same for both direct and sectional warping routes. Below 20,000 m length one has to look at the set up time and processing time required for both the systems. Main loss of time is for creeling at warping and at sizing stages. Also with the help of systems approach, a model can be generated considering various parameters to arrive at an optimum production routing to cater the requirements of smaller lots. For running smaller lots normally direct warping is not suitable as the time required to set up creel will be very high so other efficient options of creel should be tried.

2.2.6 Problems of Calculating Movement for Sectional Warping

As mentioned earlier, sectional warping machines are of mainly two types: Older machines having adjustable cone height and newer machines with fixed cone height. In newer models, as the cone height is fixed, it is required to adjust the traversing speed of the carriage. It is extremely important to calculate the value of the amount of traverse speed of the carriage with very high precision as the quality of the beam and tension of individual threads after beaming depend on this value. This value is also important from the point of the length of total yarn which can be wound on the drum. As mentioned by the authors, so far there is no precise calculation method for the same. The number of variables which affect this adjustment are many and the height of section build up is affected by each parameter. There is one method of measuring this value with the help of laser sensor (16). This method simply measures the value of the feed of the traversing reed required with each rotation of the drum so as to enable precise winding of the warp thread throughout all the sections and to make sure of the equal tension of all sections during the beaming operations. Still the amount of the yarn which particular drum can hold is not increased to great extent.

Many scientists have worked to derive mathematical equations to work out warp sheet thickness on cone build up. This will help in deciding maximum length which can be taken on drum for a given set of parameters of yarn. Liute and Racu (17) have derived equations relating speed of the motor for driving the drum and axial speed of the carriage. They have also taken in to consideration the thickness build up, with reference to particular yarn linear density, on the drum surface. The equation is validated on Benninger sectional warping machine. They also have mentioned about using a computer interface to determine correct traverse speed. The problem of increasing the yarn content on a sectional warping system has not been addressed in the paper.

Similar work on mathematical analysis of motion control in sectional warping machine has been carried out by Eren (18) et al. They have derived an equation to calculate warp sheet thickness based on winding density. Warp sheet thickness calculated from the warp length and number of drum revolutions showed a good agreement with the measured warp sheet thickness. The experimental work was carried out on Benninger Sectional warping machine. As per the claim made in the paper, the equation enables precise calculation of warp sheet thickness and the number of drum revolutions and thus eliminates the need for any sensor to be used for measuring warp sheet height. They concluded that mathematical equations enable the winding to the drum as well as to the beam at a constant surface speed without using a speed measurement sensor and feedback control system.

Some other papers published (19,20,21) are mainly related with the developments which have occurred over various ITMA exhibitions with reference to improved performance, increased productivity, quality of beam, ease of work etc. for both direct and sectional warping machines. These papers mainly talk about newer additions for various manufacturers.

2.3 Patents

As mentioned in earlier part that not much work has been available in published literature to find unified solution to warping system. The problems of either running patterned warp on direct warping or trying to increase the yarn content on drum of sectional warping have not been addressed fully. Some of the attempts have been published as patents and a review of such patents registered or applied so far will be discussed in the coming sections.

2.3.1 Modifications in the Creel

The creel used for either direct or sectional warping has more or less same features. Over the period there has been a lot of development in creel. These are mainly aimed at increasing the number of bobbins to be accommodated, decreasing the distance between creel and head stock, reducing the creeling time by providing many options etc. These facts are already mentioned in most of the textbooks on weaving (22, 23, 24).

There are some patents which represent novel methods of organizing creel which are briefly discussed below.

2.3.1.1 Circular Creel

One such attempt has been made by Colson et.al. in their patent (25). This patent was registered in 2003 in USA. This is regarding a totally new concept of organizing the creel to be used for warping. As shown in figure 2.1, the creel is arranged in a shape of circle.

As per the discussion in the patent, this helps in maintaining an equal distance to be travelled by all threads while reaching the head stock and so the force required to pull the yarn will be same for all threads. The yarn passes through a guided path and finally wound on the beam. A turn table that supports two or more beams is provided to facilitate the rapid switching of beams once one beam is full.

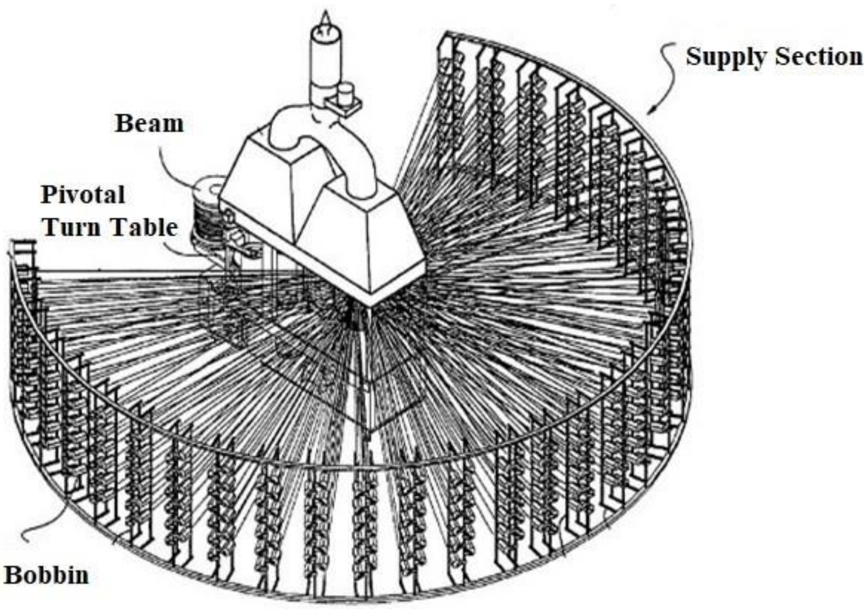


Figure 2.1 Novel method of organizing Creel (25)

Another view of the creel is as shown in figure 2.2 which shows a cross section of the creel and the guiding roller arrangement which can have heating system for preshrinking of the yarn.

Merits:

The arrangement shown in the patent is applicable to direct warping and one of the objective is to increase the size of the creel.

Demerits:

The capacity of creel is smaller compared to the ones available currently. Today there are machine manufacturers providing a creel of 1200 for the direct warping system.

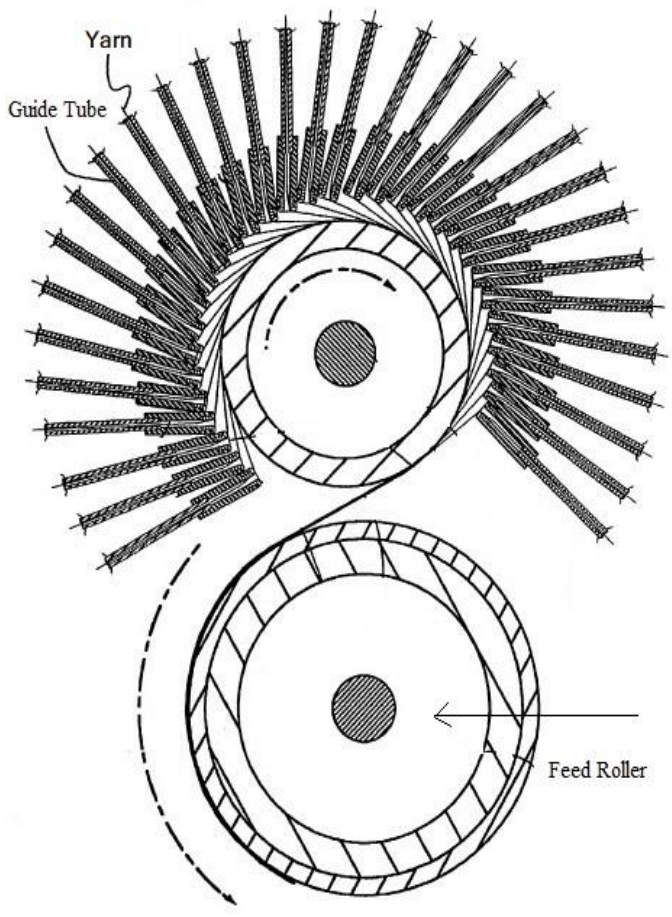


Figure 2.2 Cross section of the creel arrangement. (25)

2.3.1.2 Automatic switching of threads in creel

Yet another patent was filed by Hiroshi and Shozo (26) regarding automatic switching of patterned warp on a sectional warping machine. They have tried to provide solution to the problem of reducing creeling time which is lapsed when running patterned warp. Also changing the creel at the end of the beam is a highly time consuming operation.

Again first and the last sections of the beam require a different number of threads as selvedge threads will be included. The arrangement is as shown in figure 2.3. Each position in the creel has a knotter attached to it. So as and when required the knotter, operated by a motor and controller, can switch the yarn by carrying out the knotting operation. The switching mechanism is as shown in figure 2.4.

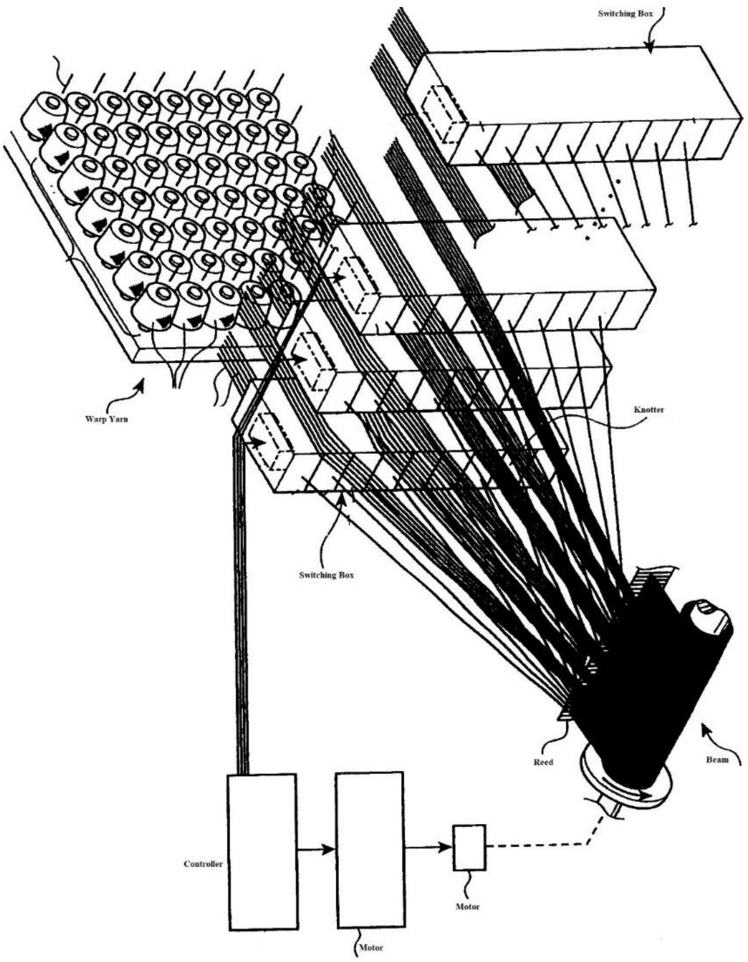


Fig. 2.3 Arrangement of switching creel (26)

Demerits:

This system offers a novel solution but is limited to very less number of the bobbins in the creel. In the patent a total of 148 positions have been considered.

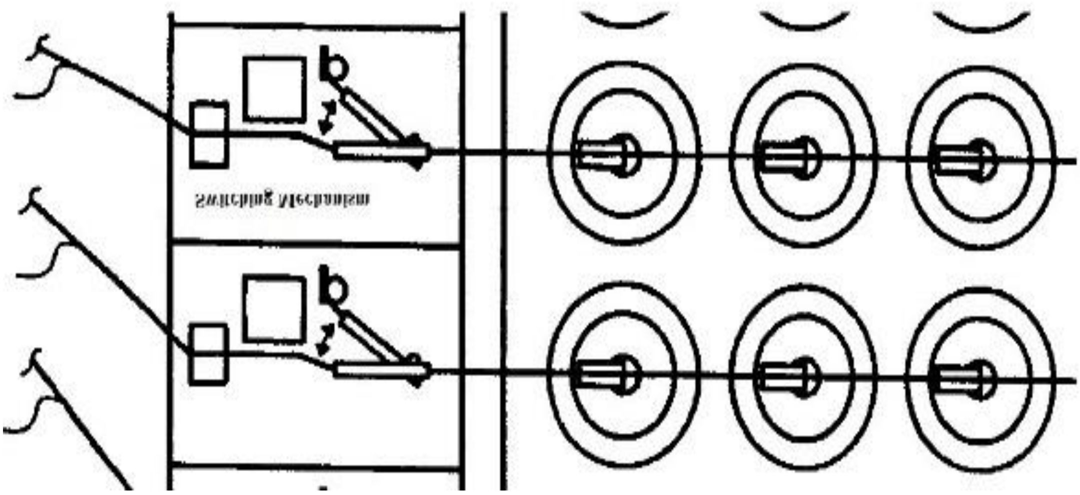


Fig. 2.4 Switching Mechanism (26)

2.3.2 Modifications of the beam flanges

There have been many attempts about modifications of the flanges and thereby make the system more flexible in one or the other terms. In very early days the beam used during warping was entirely made of wood and it was highly difficult to control many parameters during later on processes.

2.3.2.1 Use of metal sleeve

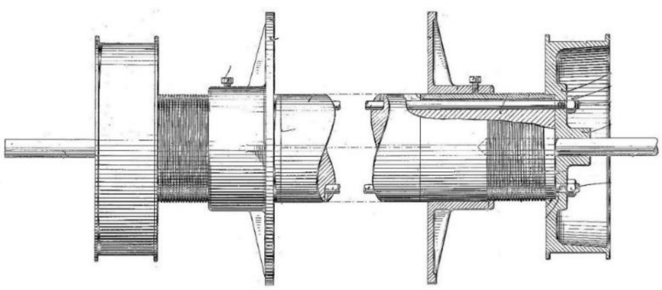


Fig. 2.5 Wooden beam with metal sleeves (27)

The first patent was registered in 1922 by Balthasar (27) about use of the metal sleeves at the end of the flanges. The patent diagram is as shown in figure 2.5 above:

The purpose of the invention is to provide a warp beam having its roll portion made of wooden end portions, for a distance sufficient to cover the range of flange adjustment desirable. It is provided with cylindrical steel sleeves formed and sized, on which the hubs of the flanges are mounted with possibility of sliding. While the clearance may be as small as 0.001 inch so that it will not hinder the warp threads in any way.

In line with the previous patent, another patent was filed by Olson & Swenson in 1938 (28). The basic arrangement is as shown in figure 2.6 and figure 2.7.

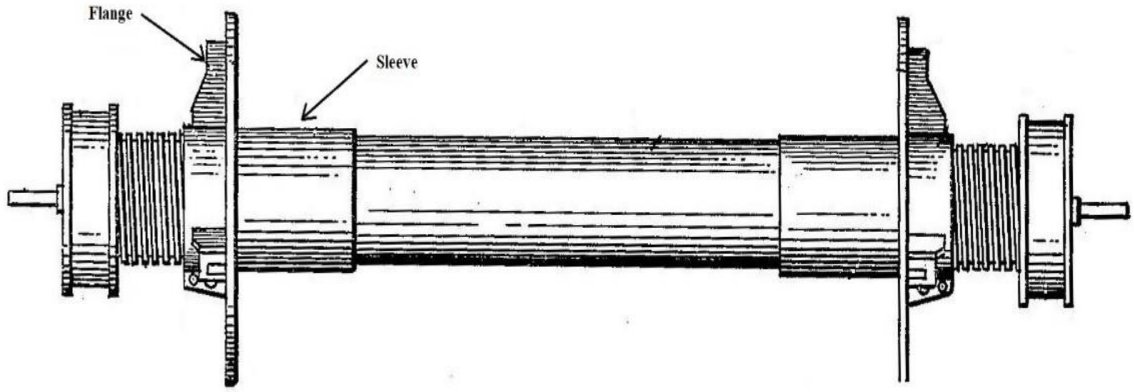


Fig. 2.6 Warp beam with a sleeve (28)

As shown in the figure that the flanges are adjustable on both the sides and at the same time there is a metal sleeve covering the threaded potion on the barrel. The sleeve is attached over the flanges which means that the sleeve can be moved by a desired distance after adjustment of the width in such a way so as to cover the threaded portion fully on both the sides.

As per the claim made, this provision helps in protecting delicate threads against abrasion due to threads made on the barrel. But at the same time, there will be slight overlap within the roll surface. Though the overlap is quite small but can cause some problems for heavy sett varieties. A screw is provided to fix all this parts together during the running of the beam on warping machine.

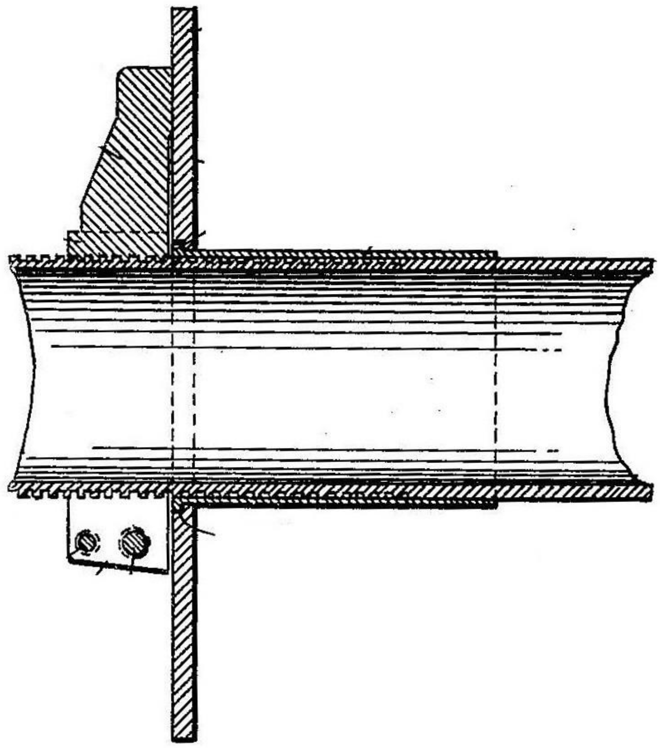


Fig. 2.7 Detailed view of the flange with sleeve (28)

A patent filed in 1958 by Harris (29) is still one step added in to previous two patents. The invention is about the modified design of the flanges and means of fixing flange onto barrel. The basic idea is to avoid the damage that occurs to yarns when flanges run on threads made on to the barrel surface. Due to this sometimes scratches, cuts etc. happen on barrel surface and cause damage to some of the delicate yarns. Also the lock nuts or mechanism used to fix flanges on barrel cause damage.

Both the problems have been taken care of by means of providing new design which has teeth made on inside of flanges and barrel. The arrangement is shown in figure 2.8 below. The patent also has a provision in the design of an improved method of assembling flange and the barrel.

The main barrel is hollow and inside the main barrel there is threaded roller. A pin (or the shaft) mounted on both ends of the flanges have a gearing arrangement which meshes with pinions mounted on another shaft which are not shown in the diagram.

This arrangement will be used to carry out width adjustment of the beam as and when required. The patent provides a novel solution to adjustment of the width of the beam. Currently all beams are provided with an accurate width adjustment possibilities without causing much of the damage to warp yarns. But still all beams have an exposed part of the threads where initial layers of the warp come in contact with. For very delicate yarns a smooth surface will be preferred.

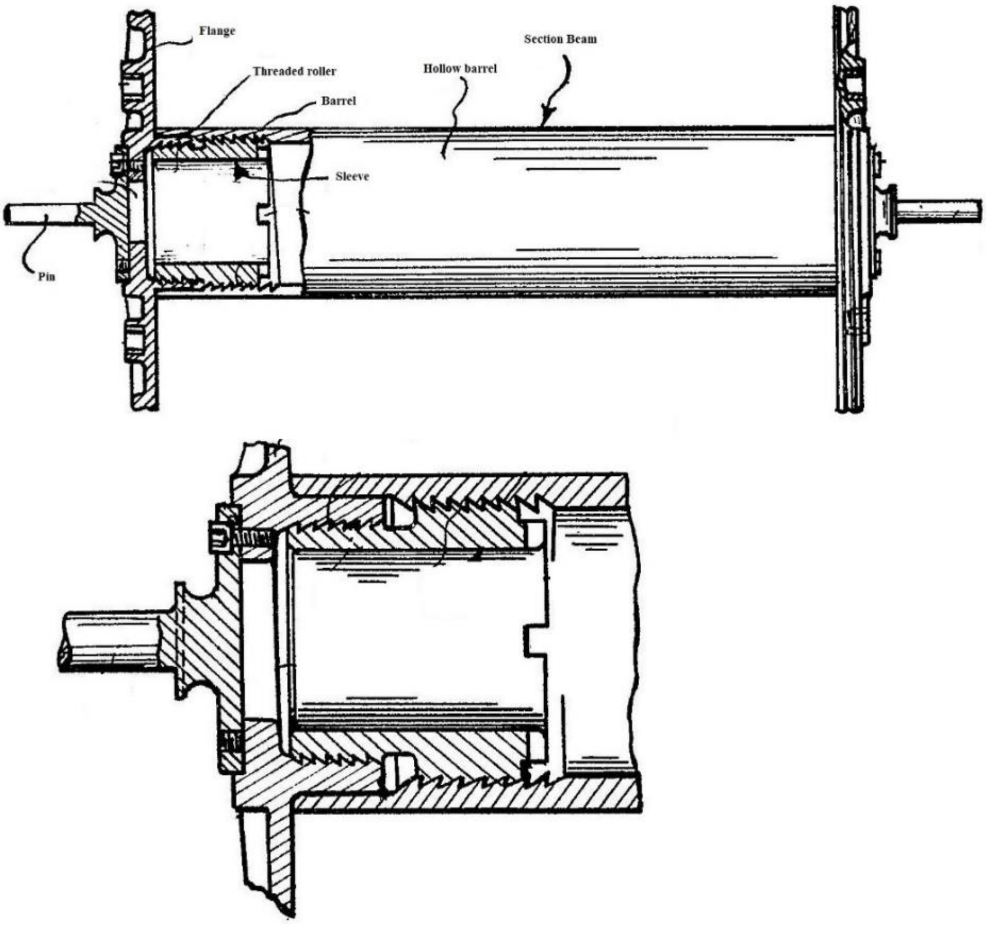


Fig 2.8 A novel design of flange and the barrel with a detailed view as inset diagram (29)

2.3.2.2 Modifications based on smaller beams

The requirement of beams is there in warp knitting also but the warp knitting process requires beams of usually narrow width. There are many patents filed for various design issues of beams meant for warp knitting process. Some of the relevant patents can be applied to a higher width beams also and can be used on warping systems.

A patent filed by Storey (30) is related to modifications in the warp knitting beams. He has mentioned that fixing flanges on a barrel involves many parts and complexity of adjusting the same on the barrel. Also the material used is quite heavy and causes problems during shipping internationally. These problems were addressed by Storey in his patent. The objectives as stated in the patent were as below:

(i) Use of light weight beams

(ii) Simplified manner of mounting

(iii) Decreasing thickness of the flanges

(iv) Limited play after fixing of the flanges

The flanges were made by aluminum or aluminum alloys to reduce the weight. Also in place of threaded part on the barrel, a plug mounted on barrel and pin mounted on the flange arrangement was offered for fixing the flange. A typical arrangement is as shown in the figures 2.9(a) and 2.9(b) below.

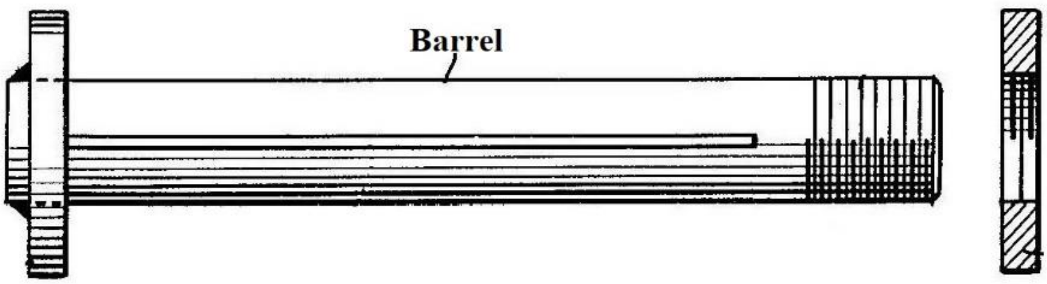


Fig. 2.9 (a) Warp knitting beam as per Storey (30)

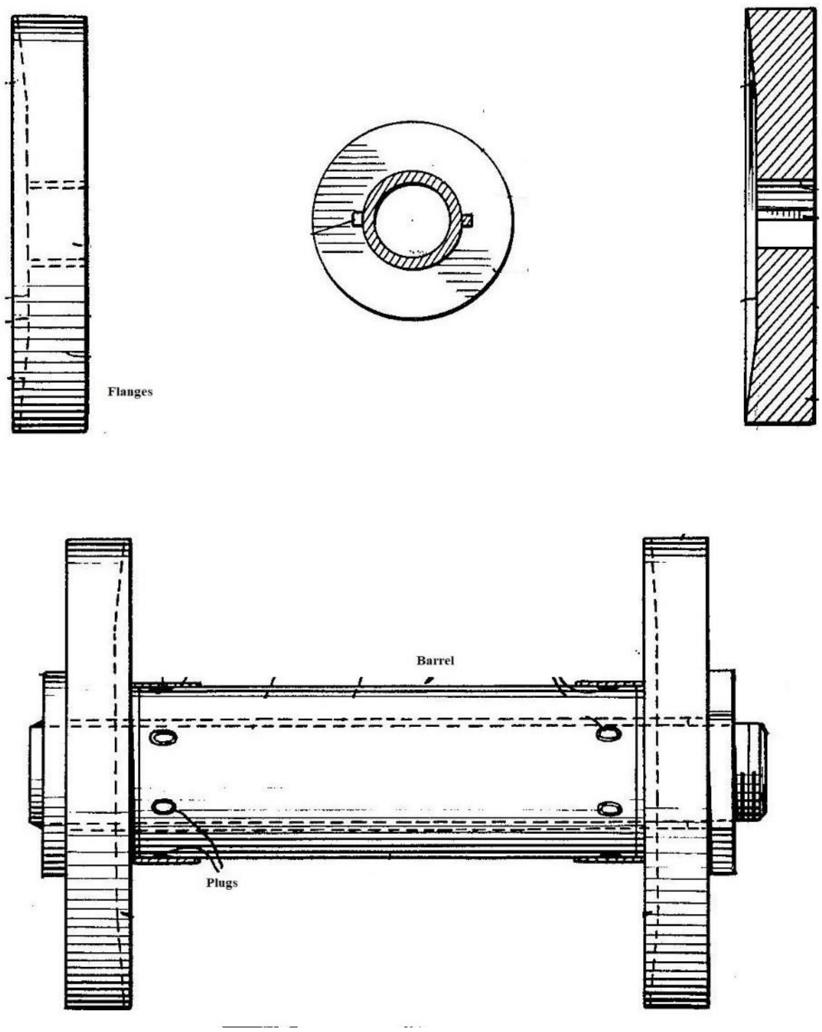


Fig. 2.9 (b) Warp knitting beam as per Storey (30)

The invention relates to warp beam used for narrow width but similar arrangement can be used for higher width warp beams too. Evidences of the work being carried forward are not available in published literature or in the patents.

2.3.2.3 Flange with metal and coating

A similar patent has been filed by Hubert et al (31) regarding the material to be used for flanges. His attempt was about mainly reducing the weight of the flanges and thereby increase the speed of the warping and reduce the overall cost. The design of the beam is as shown in figure 2.10.

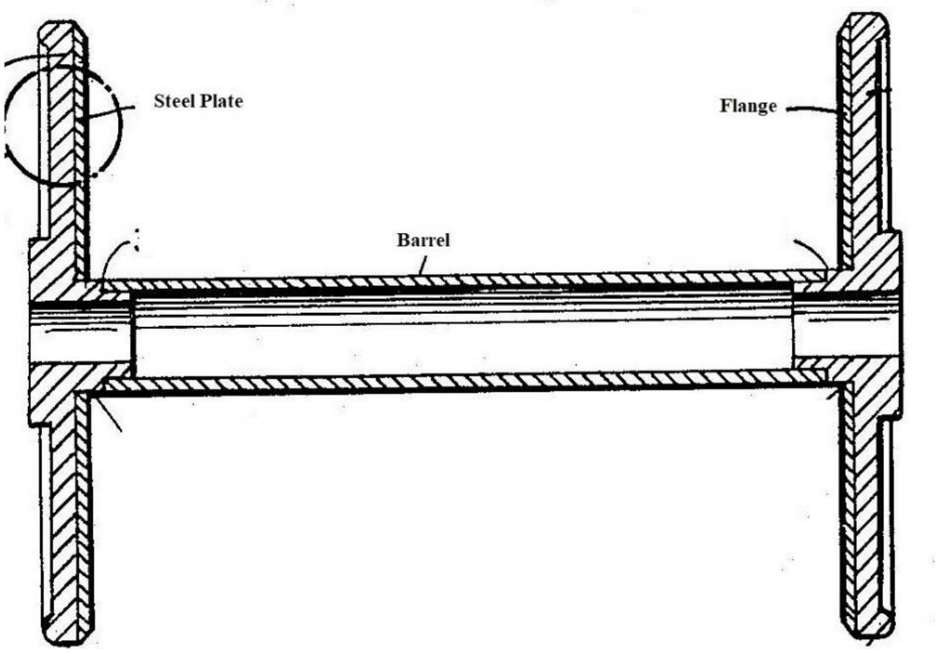


Fig 2.10 Light weight beam flanges (31)

As per the claim made, it is possible to use a very thin steel plate with a thickness of about 0.5 to 3 mm., preferably 0.8 to 2 mm., as a means of protecting the flange inner surfaces without substantially influencing the economy of weight and proper functioning of the warp beam as achieved by the use of a light metal. The impact resistance of the steel is at least 60 kg/Sq. mm.

Furthermore, the abrasion resistance of the steel surface can be best accomplished by means of a hard chrome coating. Thus a steel plate coated with a chrome layer having a thickness of 0.02 to 0.05 mm is sufficient to avoid substantially all of the difficulties which are caused by thread or yarn abrasion and especially by impact damage during transportation of the empty beam.

It is extremely important that the thickness of the steel plate with or without the chrome surface coating be kept as small as possible to avoid an excessive total weight of the warp beam. In this respect, the ratio by weight of the steel plate to the warp beam composed of a light metal must be maintained below a value of 1:15 to 1:10 depending on the warp beam size and length.

2.3.2.4 Conical shaped flange

One more interesting patent has been filed by Fuhr (32) for Karl Mayer Company. The patent has been filed in various countries and currently European filing is considered. The flange of the beam is differently designed in this patent as shown in figure 2.11 below. The full view of the whole system during working is as shown in figure 2.12.

As shown in fig 2.11, the flange itself is shaped in to conical way. The angle of the conical surface can be up to 45 deg but in the patent it is recommended to keep it up to 20 deg. As mentioned earlier that the sectional warping machine works with the one side conical shaped drum. The same function will be carried out by the beam itself.

The sections will be wound on the beam directly one after the other till all ends are wound on the beam. During winding of the sections, as the beam rotates, there will be lateral shift of the sections which is similar to sectional warping. The mechanism, as shown and written in the patent literature, for shifting is similar to sectional warping machine. The beams later on can be taken to sizing or on the loom shed directly.

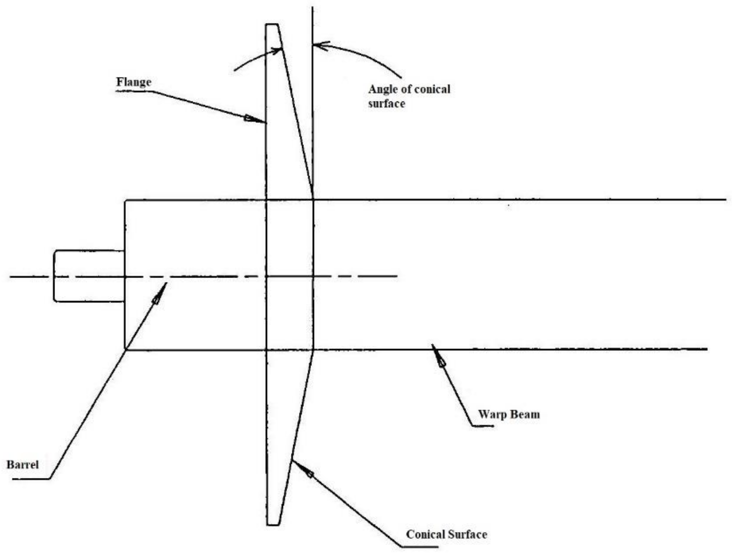


Fig. 2.11 Conical beam flange (32)

When the beams are mounted on either sizing or on the looms, the lateral shift in the opposite direction will be required due to unwinding of the beams. There is no mention in the patent about this motion. The patent mentions that as the speed of unwinding is comparatively slow at later on stages, there will not be any problem.

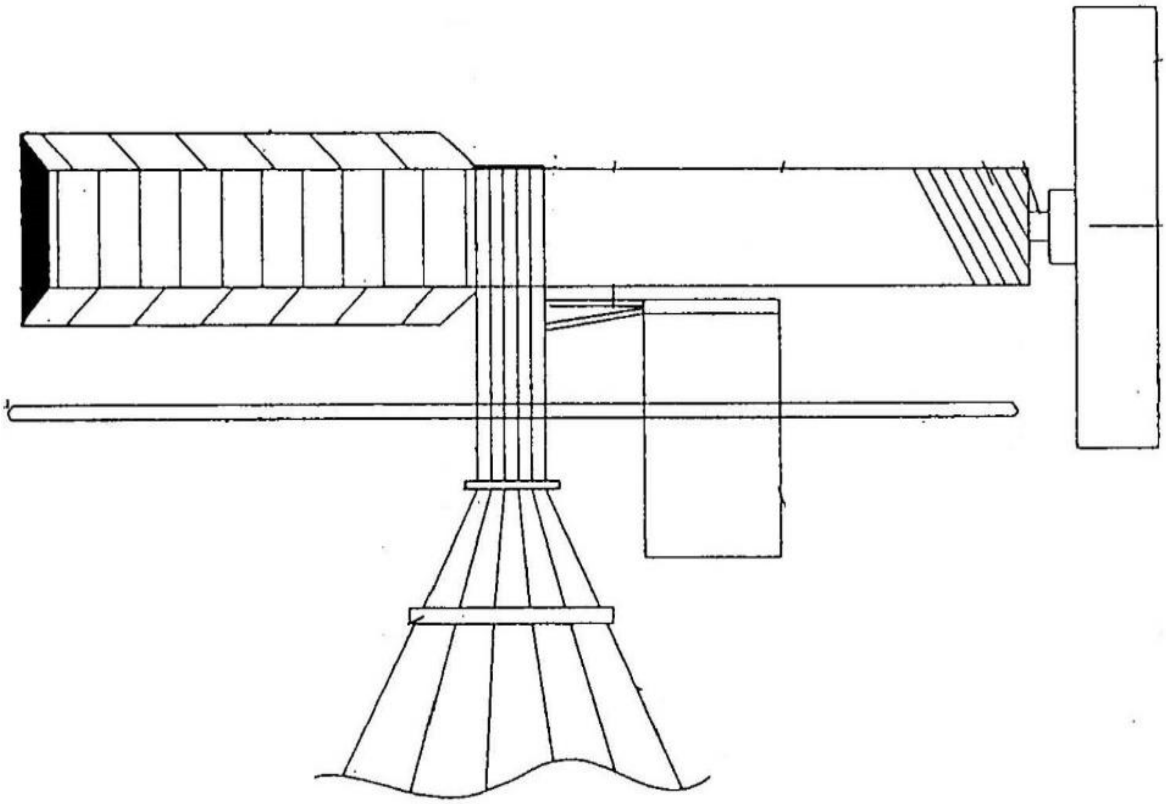


Fig 2.12 Full view of the conical flange in use (32)

Today's sizing machines or looms are working at very high speeds. So, in absence of any mechanism for shifting of the beam, many defects may arise. Another problem with the design is that only small length of the yarn can only be taken on the beam as very large length will require higher amounts of lateral shifting which may not be possible. Also higher length will require different angles of the flange conical surface as well, the answer to which is not provided in the patent.

2.3.2.5 Patent about width adjustment of weaver's beam

In yet another patent Zhang et al have provided a modified design of the weaver's beam (33). The same concept can be applied to other beams also. The design is as shown in figure 2.13 below.

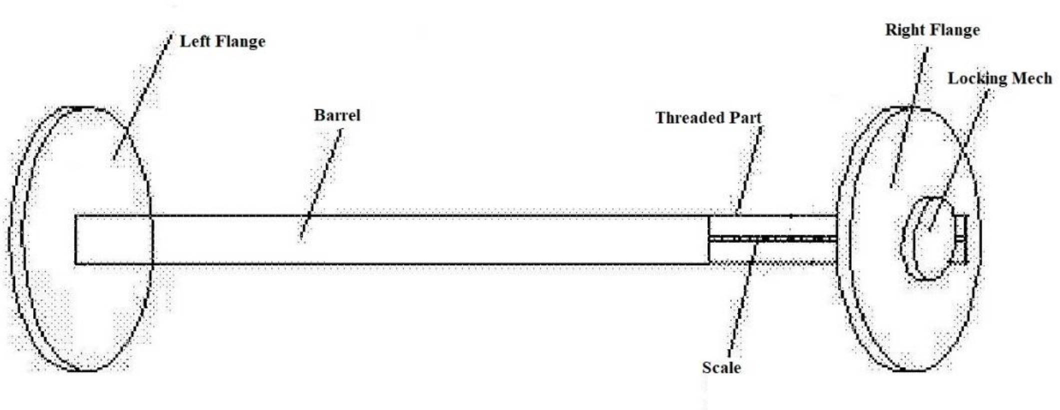


Fig. 2.13 Modified design of weaver's beam (33)

As can be seen in the figure, the left side flange of the beam is usual but the right hand side flange is designed differently. The main idea behind the invention is that of removing width measurement done by using measuring tape. Using measuring tape requires more time and sometimes can lead to errors also. In place of normal threaded barrel and toothed surface of flange, the barrel is smooth without any teeth and the flange also does not have any teeth.

The right side flange has an inner part which is threaded. There is a fixed scale also to measure the width accurately. After adjustment, the flange can be fixed using a locking mechanism. The invention claims that the beam is meant for an air jet loom, but as can be seen, the idea can be utilized for beams to be used for any other loom too.

2.3.3 Sections in the beam

Many patents have been registered about making sections in the beam and thereby run the beam to warp patterned yarns. Also some patents are registered for making the beams for warp knitting operation but the same can be extended to beam warping process also and are discussed here.

2.3.3.1 Early version of sectional warping

In 1935 a patent was registered by Loncteaux et al from USA (34). The patent is mainly an early version of warp knitting beam making machine or sectional warping with claims of increased speed, better control over threads and improved braking mechanism. The early version of mill winding and then beaming have been taken care in to one operation. The arrangement is shown in figure 2.14 below.

Also claimed was the dividing plates with a small number of threads in a particular section. Possibility of adjusting the width between plates was effected by means of mechanical adjustments or can be done manually. This version is about sectional warping with claims of higher speed, improved control over threads and better braking mechanism. The means for sliding the thread table are also provided and are operated manually. The height of the thread table is kept adjustable so as to keep it aligned with the warp throughout. It has provisions for various kinds of stop motions also.

The beams so prepared can be used individually for warp knitting operation or the whole beam can be taken in to next operation. There is no mention about the thickness of the dividing plates and the effect of the same on overall thread density in the beam. Also the number of threads are less and the length of the yarn on the beam is less as well.

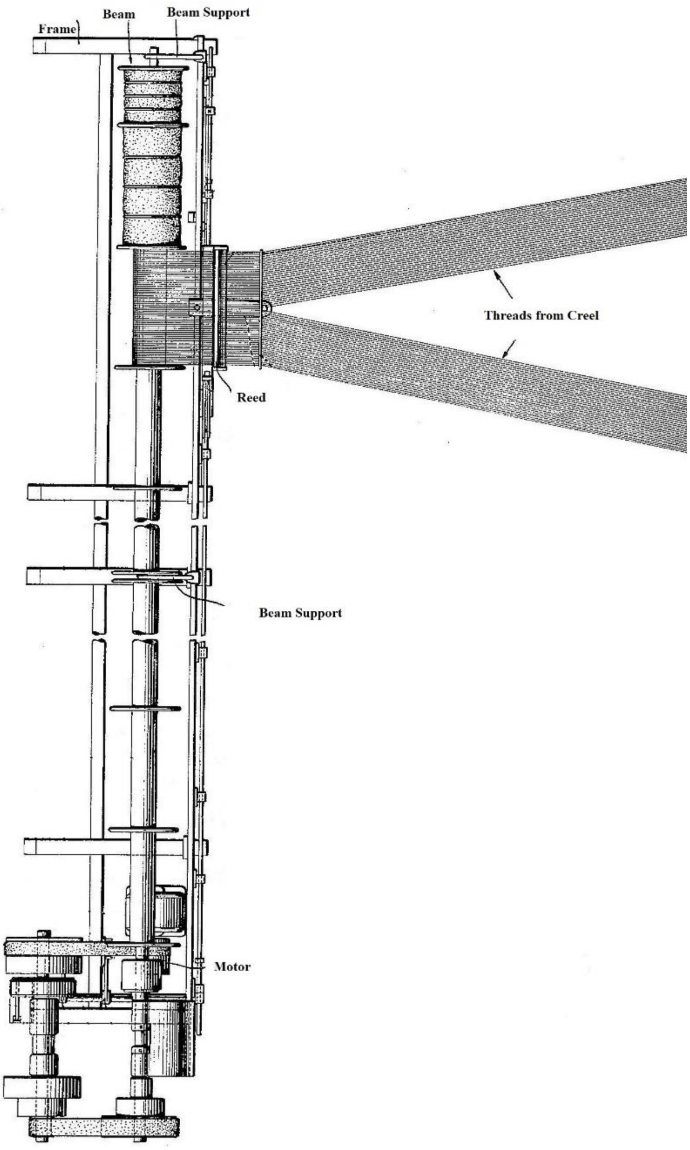


Fig 2.14 An early version of sectional warping (34)

2.3.3.2 Patents about setting warp on beam

There are two patents by the Payne (35, 36) regarding how to fix warp yarn on the beam. The beam normally has holes made on to it to fix the knots of the sections of the threads to be fixed. These knots sometimes create a bulge on the surface of the beam which leads to uneven top surface of the beam. This can have an adverse effect on the tension variation across the width of the beam. Both inventions mainly relate to weaver's beams to be used on the loom but the same can be applied to warper's beam as well. Of course there is no such mention in both patents regarding use of this invention for warper's beams.

The background for the invention is that the barrel is made of wooden material which under the pressure of threads may get damaged. Also the initial layers of the threads will exert more pressure due to knots made on to them leading to deformation of the barrel surface.

In the first patent (35) Payne has described a sleeve which is to be fitted over the barrel after the first wrap of the thread is wound on to it. The sleeve has a cut made on to it which will be compressed under the action of the tension generated by the winding of the threads and thus the slippage of threads, which normally was common to wooden barrels, can be avoided. This sleeve was made of steel to make it more resilient. The flanges are normal as usual and have the width adjustment similar to the ones found with wooden barrels.

In the second patent by the same inventor (36), slight change in the sleeve is made. The main purpose of the sleeve is still the same i.e. gripping the warp threads. The sleeve, made in to parts, will have longitudinal slots cut on to it. The sleeve is made with slightly more thickness.

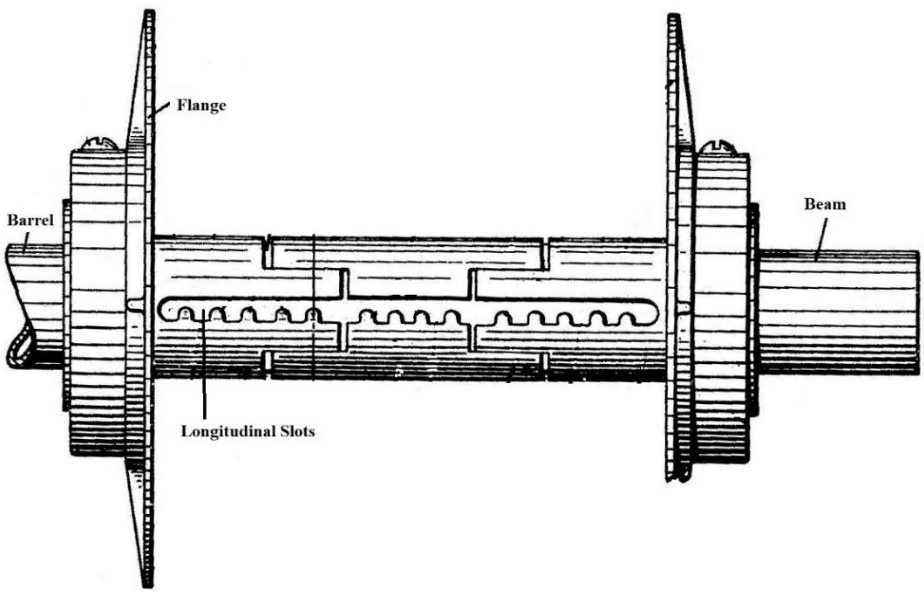


Fig 2.15 Wooden beam with metal sleeve (36)

The figure 2.15 shows the design of the beam. In modified design, there are longitudinal slots made on to sleeve with holding lips which will be compressed when initial layers of warp will be wound on them. The sleeves have been attached to both side flanges separately.

Though patent is mainly about providing grip to the threads for wooden barrel, the idea can be further explored with modifications which can be used on either direct or sectional warping.

2.3.3.3 Problems with beams to be used for multi width working

On the similar lines, another problem related with the beams to be prepared for multi width working was attempted by Erwin in his patent. While working with multiple beams on the same loom, e.g. Sulzer Projectile loom, maintaining the same drive ratio for all the beams and extent of rotation of all beams become highly important parameters.

A US patent was registered by Erwin P. for Sulzer Brothers limited in 1978 (37). This patent is further modification of yet another patent filed by Scholze G. et.al. (38) in 1974. As per Erwin, the multi-component warp beam is made of at least two telescoping parts with a clamping means pressing the parts together radially from within the area of overlap.

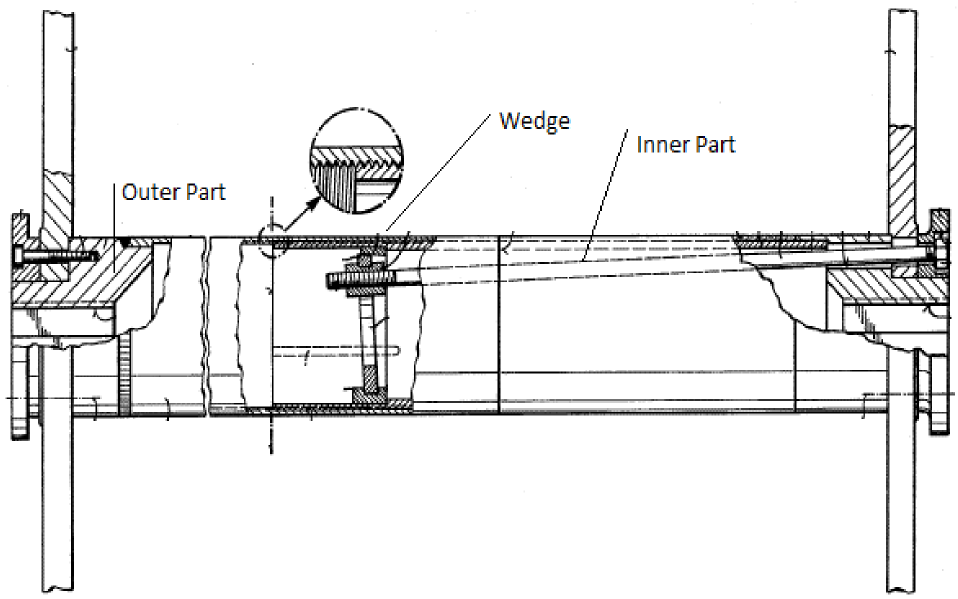


Fig. 2.16 Multi-component warp beam (37)

As shown in figure 2.16, the clamping provided includes a wedge shaped plate pressed by means of a partially threaded spindle. Again the patent is meant to provide solution to the problems while working with the multiple widths but the design of the beam suggests various possibilities for exploring further when to be used for warping system.

The wedge can be further utilized to carry out width adjustments very easily. The further attempts are not available in this direction in terms of patents or actual design of the beams used on current machines.

2.3.3.4 Using narrow width beams for normal yarns

In yarn-warping devices intended especially for pattern and short warps, a large number of threads are successively wound in section form and all the wound sections are rewound onto a single warp beam by means of a re-beaming process. The patent filed by Kuesters (39) et al offers novel solution to this problem. The patent has been assigned to Hacoba.

As per the patent, small width beams, according to the section widths, are to be prepared which later on will be combined and a final weaver’s beam containing all threads will be formed. The winding of the sections will be done one after the other and there is an arrangement in the design to shift the railing further and align with the next beam.

The main limitation of such a system will be less length of the yarn which can be warped. This is due to later on process where all beams are to be combined which will require huge space if the diameter of the flange of the narrow width beam is increased. The design of such a system is shown in the figures 2.17 and 2.18 below. As can be seen in figure 2.18, the small diameter beams have been mounted in staggered manner. If used for patterned warp, the arrangement of complex patterns will be very difficult and very high time consuming process. Using of the system for single coloured warp seems farfetched as it does not offer any advantage over a direct warping system. Also mounting all beams and taking them out will also consume higher amount of time. So it can be stated safely that the system may have a use for sampling situations.

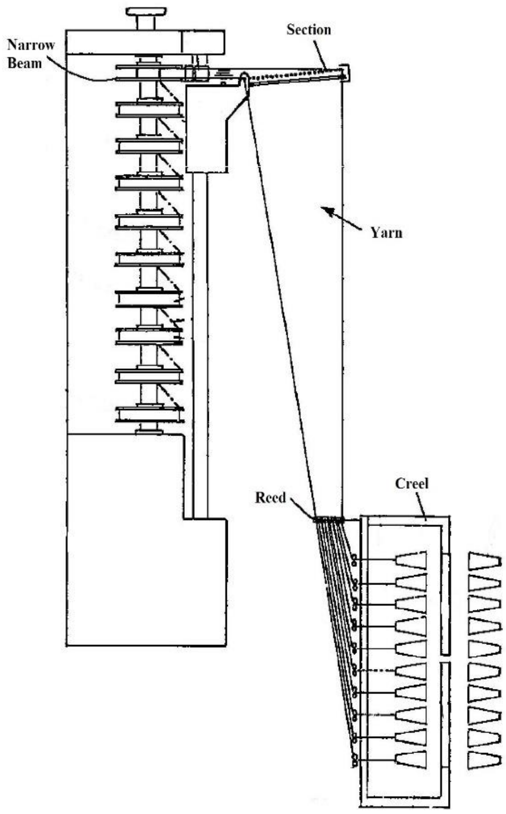


Fig 2.17 Narrow Width Beam (39)

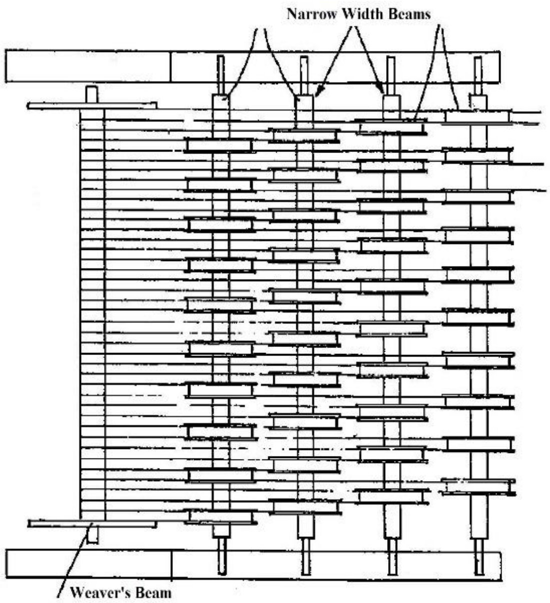


Fig 2.18 Final beaming (39)

2.3.3.5 Using narrow width beams for specialty yarns

Many problems are encountered when any special type of yarn is to warped either on direct or on sectional warping. One such yarn is high twist yarn. The invention by Agnihotri (40) is about a design of an apparatus for warping high twist fine count yarn on a direct warper over a narrow width and then dyeing the same on a slasher indigo dyeing machine. The invention is assigned to Arvind Ltd. The main problems while working with high twist fine count yarn was higher end breakage rate which leads to entanglement. Use of narrow width beam permits better control over thread especially when higher tensions are to be applied. The pressure roller is also adjusted accordingly. All rollers were aligned with the line of warp so as to reduce tension on the thread. The use of narrow beam was to increase density of ends and thereby to reduce entanglement. So it may be possible to extend the logic to other yarns too. Figures 2.19 and 2.20 show the part of the work reported in the patent. The other part of dyeing is not included currently.

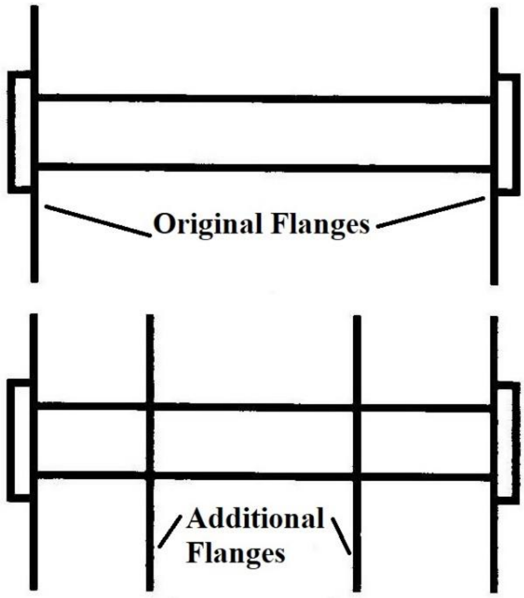


Fig 2.19 Narrow width beam specially made (40)

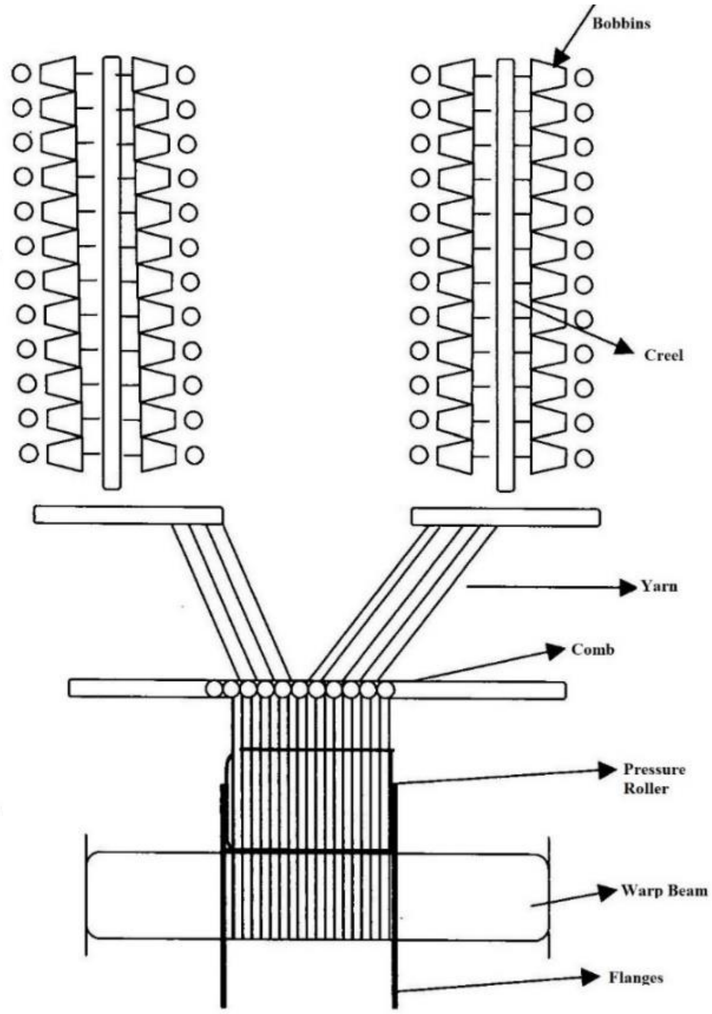


Fig 2.20 Narrow width beam for fine count high twist yarn (40)

2.3.3.6 Producing two beams from one sectional warping drum

There was one another patent based on conventional sectional warping but with a modification in the beaming process. Normally one beam is produced after the sectional warping process. As per the patent by Schmitz (41) at least two beams can be produced. The design is as shown in figure 2.21 below. While starting beaming process first beam is wound. After required length is wound on first beam, second beam is started. With this modification it is possible to produce multiple beams from one warping process. Rest of the features are usual with any standard sectional warping machine.

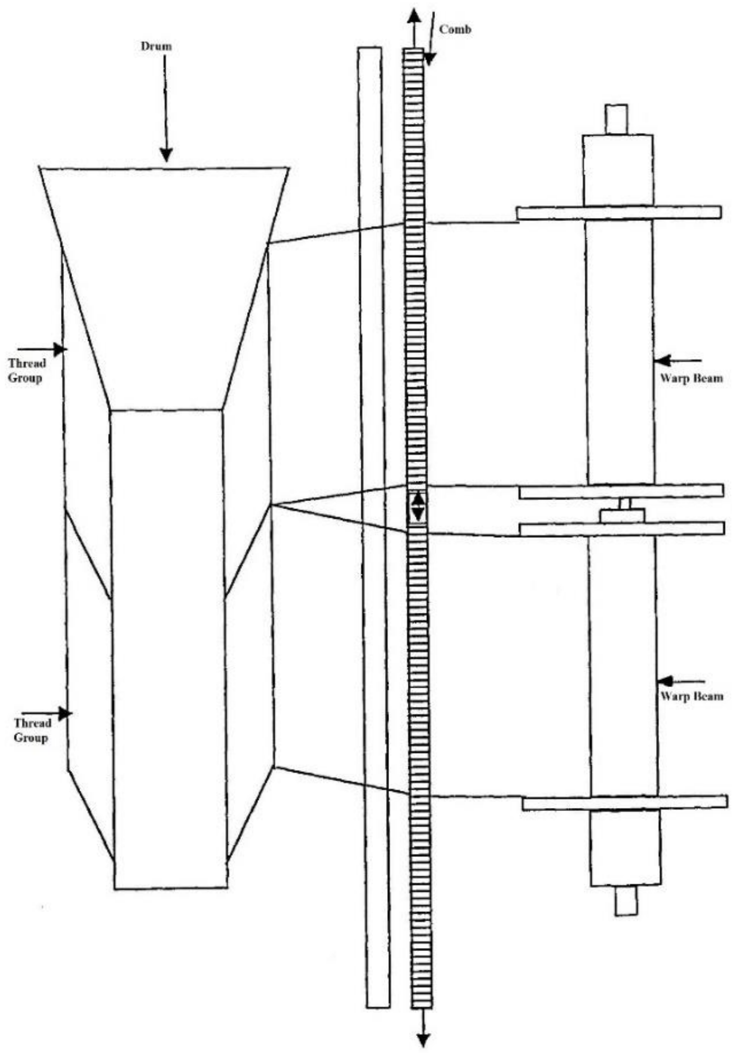


Fig 2.21 Two beams from a sectional warping process (41)

2.3.3.7 Section Beams with Separator plates

One patent filed by Yimen et al (42) reveal yet another way of resolving the issue by providing sectional beam having separator plates. As mentioned in their patent by Yimen et al, the barrel of the beam for winding the yarn has two flanges. In between two flanges two more separator plates have been arranged as shown in figure 2.22 below.

There is no mention about the distance between separator plates or between flange and separator plates. In fact it is mentioned in the patent literature that the width of the beams will be same. But looking at the diagram disclosed, it seems quite possible that the width of each beam can be adjusted as per requirement. Considering the width of the separator plates, how much will be reduction in the width and the manner in which this will be compensated later is also not part of the claims made in the patent. Also there is no clear mention about the number of ends which can be taken on to one beam.

Again there is no mention whether the invention is meant to replace any of the existing warping processes. However, there is mention about moving the beam in either direction when one of the sections is full. Other usual provisions like creel, expandable reed etc. have been used as available normally.

2.3.4 Beams with Adjustable Sections

The patents reviewed so far have one or the other modification of existing system to increase flexibility, productivity, quality etc. There are few patents which have attempted the problem very closely and the same will be reviewed in this section. When the sections made in the beam are adjustable, it is possible to adjust width of the threads. In that case it may become possible to run the beam on a direct warping machine with patterned threads.

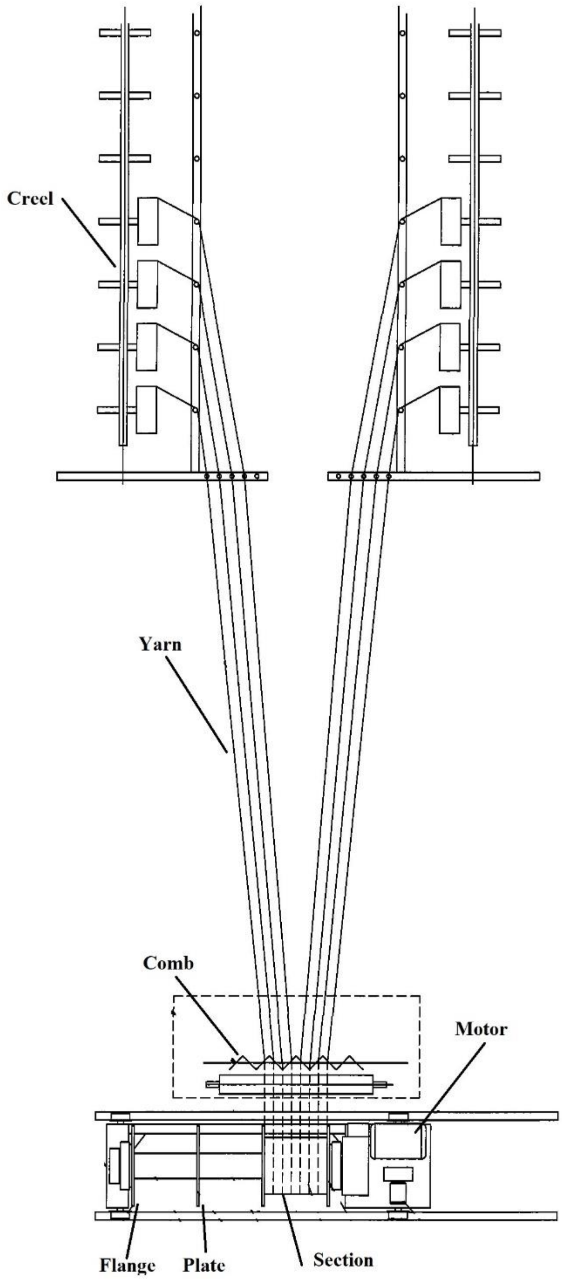


Fig 2.22 Section beam separator plates (42)

2.3.4.1 Multiple beamer for Raschel Knitting with width adjustment

One interesting and a highly detailed patent has been filed by Gaiser (43) about the winding beams for Raschel knitting machine. Of course there is quite a great difference between a warper for warp knitting and for weaving but the idea of multiple beams can be adopted for weaving preparatory also. In his patent literature Gaiser has mentioned about following problems faced by warp knitting system at that point of time:

(i) One beam or two beams only can be prepared with identical traverse. More than one beam with different traverse on the same beaming is not available.

(ii) Tension variation between yarn creel and beam for different ends cannot be controlled positively.

(iii) Occasional failure of stop motion, particularly when texturized yarns are used, occurs mainly because the yarn contains small amount of oil and oil deposit restricts operation of stop motion.

In the invention, multiple beam winding with individual adjustable traverse for each beam is disclosed. Tension adjustment is also possible. 15 to 140 ends can be wound on to three beams with width of the wound portion of the beam ranging from 190 cm to 330 cm or more. An arrangement of such a device is as shown in figure 2.22 below.

The idea has some limitation for use in weaving preparatory like there is only one end at a time or a group of ends which are wound and are traversed throughout the narrow beam. Such three beams are prepared. For weaving one needs many parallel ends to be wound adjacent to each other for a long length. But the idea can be explored further to adapt to weaving preparatory processes. There have not been many evidences weather this idea has been commercially applied by any warp knitting beam warping machine makers or it is further explored by other researchers.

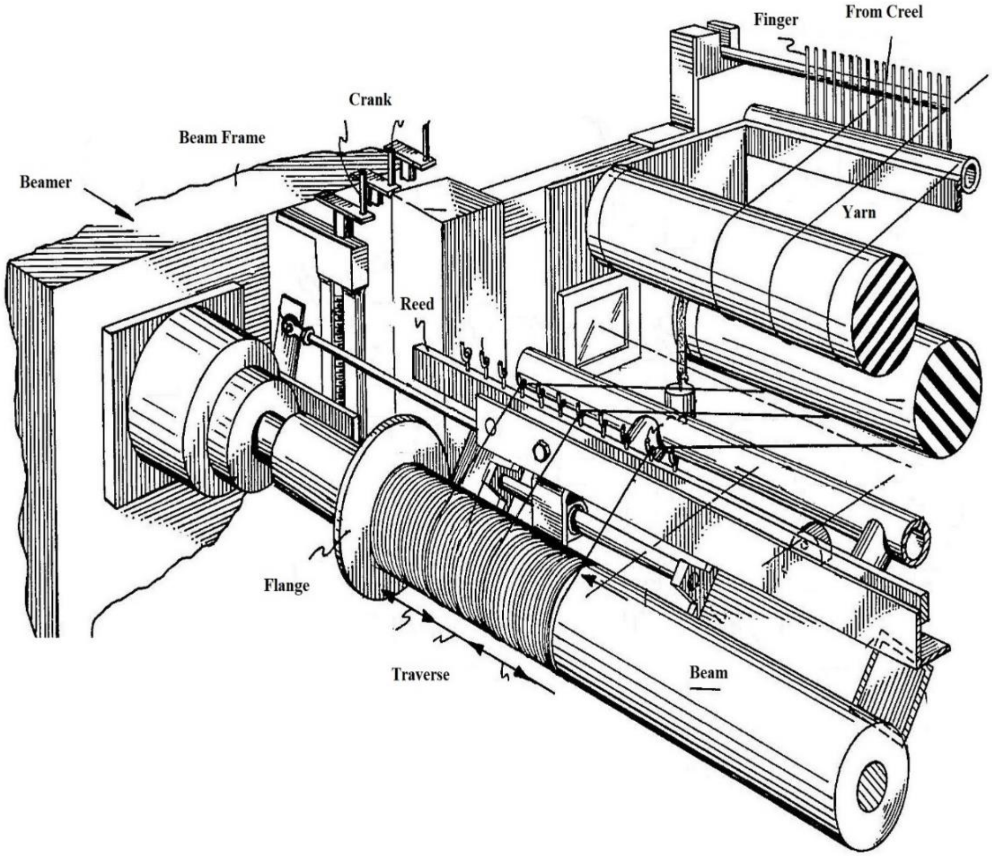


Fig 2.23 Multiple beamer for Raschel Knitting (43)

2.3.4.2 Double Warp beam Warper

In his patent Dazhang (44) has disclosed a novel method of mounting double beam on the warper simultaneously. The beams will have a common drive arrangement. At the same time it is possible to have different widths in both beams. Also both beams can run different yarn type as well. The typical arrangement is shown in figure 2.24 below. It is mentioned that the system can work with single beam also. One of the main benefits claimed is that of saving in the cost of the process. Rest of the parts can be measuring roller, adjustable reed etc. are used as per the prevailing availability. As the figure does not include the creel and other parts, it is not very clear that the arrangement is to be used on direct or sectional warping. Looking at the diagram it can be safely assumed that it is for the direct warping process and the advantage will be in terms of time saved for changeover of the beam.

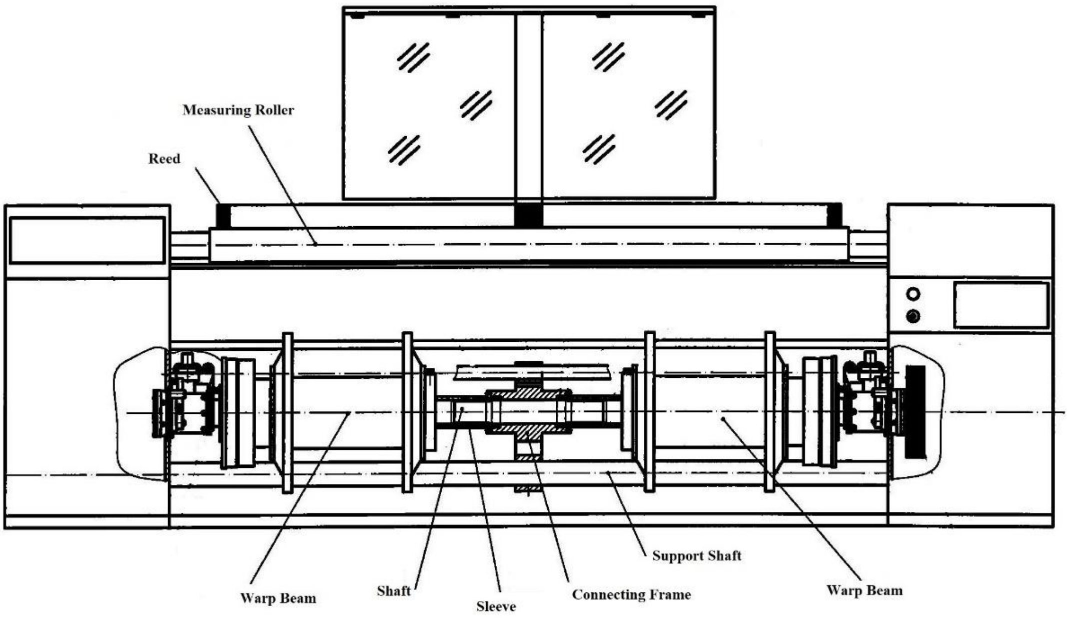


Fig 2.24 Double beam warper (44)

2.3.4.3 Double beam for warping or sizing

A slightly different patent is filed by Weifeng et al (45). The patent is mainly filed in China. The invention is about a beam which can be used on warping and / or sizing. The beam can have one more plate between two flanges. All three can be adjusted manually and further can be locked with a locking arrangement.

The number of plates between two flanges can be more also but there is no mention about the same in patent literature. Also how to wind yarn simultaneously in all segments is also not clear. The only translation is as available from Google translation facility which does not make the whole patent very clear.

It is presumed that the warping of yarn on different parts of the beam will happen one after the other. Also little can be understood from the text that the the design is more useful for the patterned warp and that it is also in some way linked to the sizing machine.

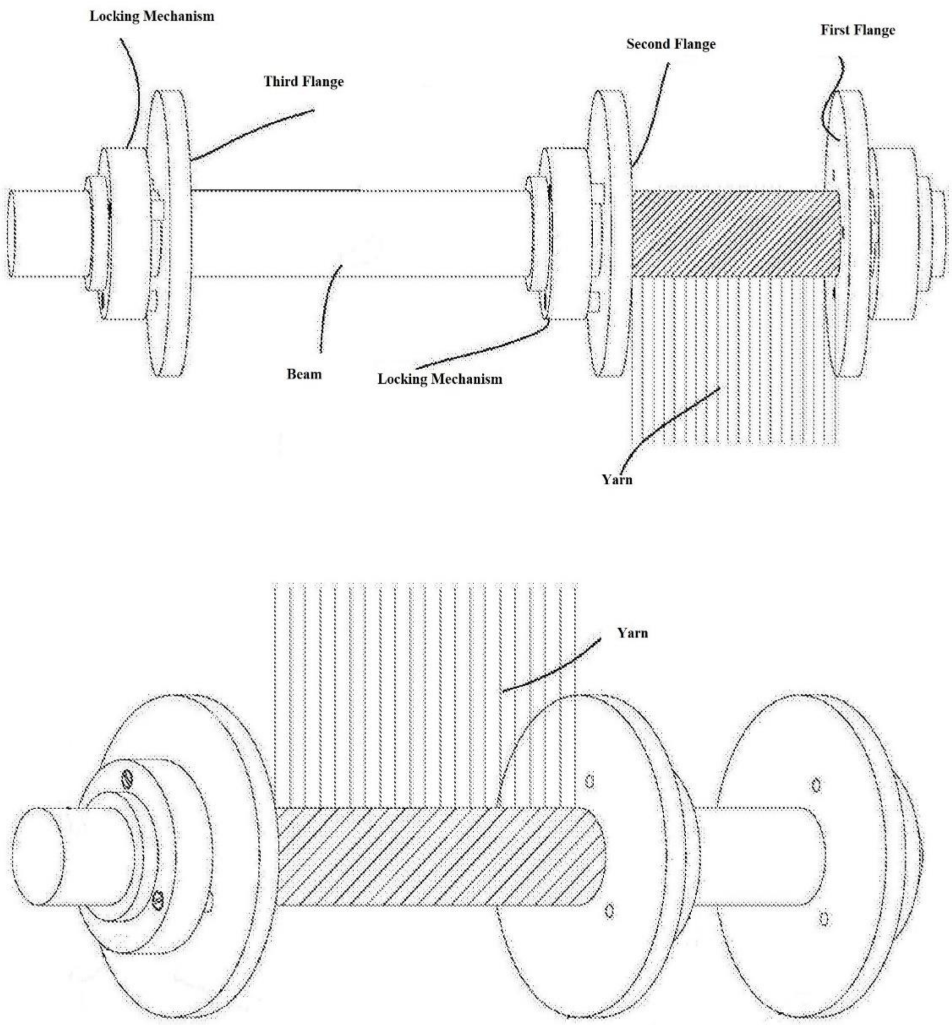


Fig 2.25 Double beam for warping or sizing (45)

Another point which can be faintly understood from the text is that the patent is mainly usable for flowering effect or may be for the double beam arrangement on the loom. This point has been made keeping in mind that the arrangement shows two beams. These two beams may be mounted on a jacquard loom which may produce figuring effect.

The figure 2.25 above shows the arrangement as published along with the patent literature. The full diagrams showing the creel segment are not available in the patent. The quality of the diagram is as available in the patent literature.

A bracket is provided to fix a particular plate in position while warping the yarn on the other side. The same is to be removed during the warping of the yarn on that side.

2.3.4.4 Dividing the warp by semicircular disc

Another interesting patent is filed recently by Zhang (46) et.al. As shown in figures 2.26 (a) and 2.26 (b) below, the invention is about semicircular plates with two bolts on two ends.

This plate can be fixed anywhere on the beam so the width of the whole beam can be divided in to two parts. Again, it is not very clear from the patent literature that there can be many more plates like the same and no mention about the way in which the width of the entire warp sheet will be managed with given thickness of the semicircular plates.

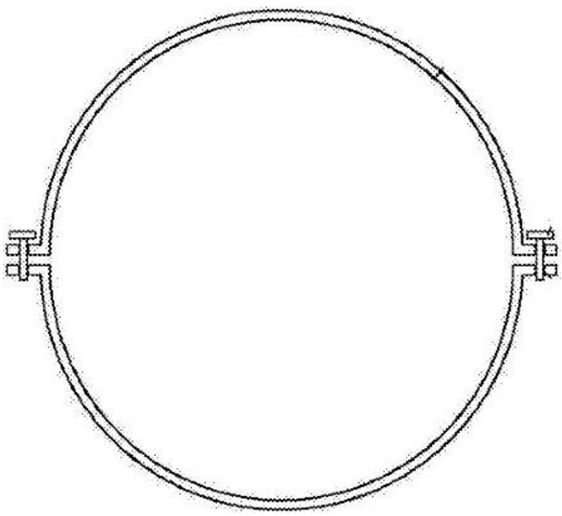


Fig 2.26 (a) Semicircular plate (46)

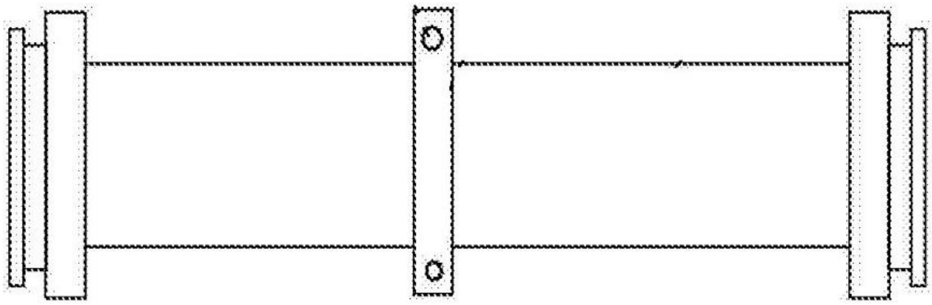


Fig 2.26 (b) Plate fixed on the beam (46)

A very similar patent has been filed by Wang (47) in China. The design of the beam plate is as shown in figure 2.27 below. There is not much change from the design of the Zhang (46) as discussed above.

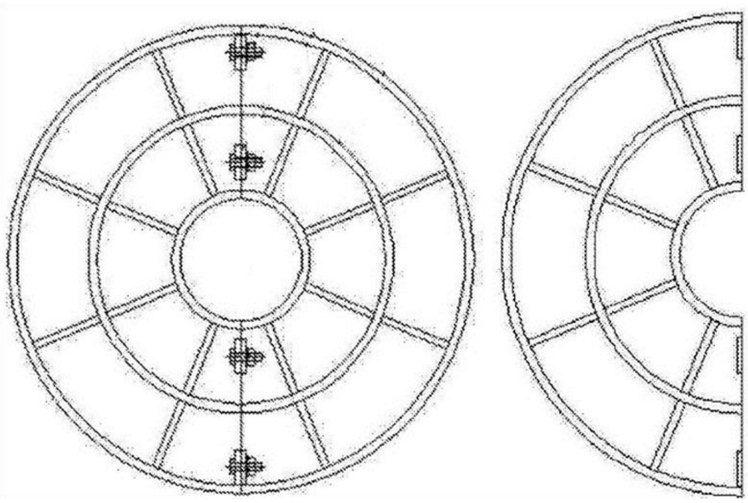


Fig 2.27 Semicircular plate for Warp Beam (47)

The advantages as claimed in the translated patent document reveal the ease of fixing the plates on the beam and thereby reduce the time for adjustments. Another difference revealed from the diagrams is that of number of locking nuts. In earlier patent it is two and in the current it is four.

2.3.4.5 Variable Separator Plates

Very interesting and a closely related patent applications have been made by Hyung (48) and Kyu (49). Both patent applications are in series so will be discussed together.

In the first patent application, a system for forming a beam with separator plates has been filed. The arrangement is as shown in figure 2.28 below. As seen in the diagram, a beam is formed having several separator plates. These plates are fixed on the beam barrel (shaft) in a variable manner.

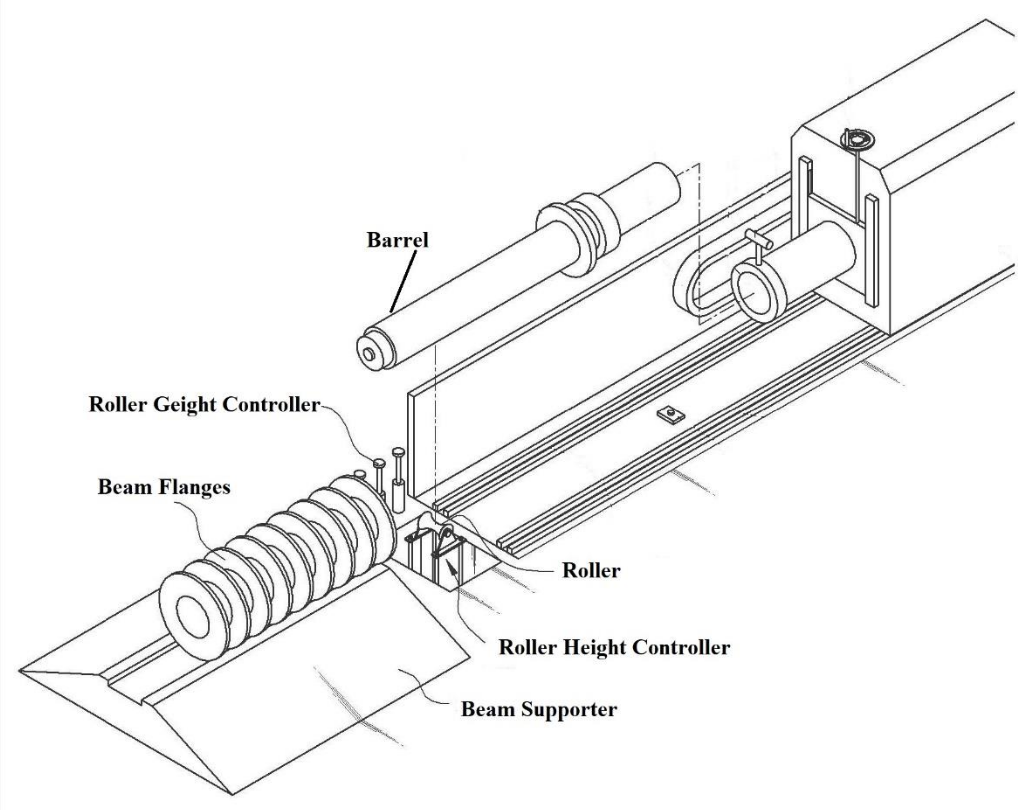


Fig 2.28 Arrangement for making beam (48)

To align the separator plates, a guiding roller is also provided, the height of which can be adjusted through a separate mechanism. The system is controlled by a programmable unit.

The distance between the plates can be predetermined as per the section width intended at the point of warping. However in the patent document and attached diagrams, it is not very clear as to how this distance will be adjusted. Another point is about the attachment of separator plates on the barrel. Again it is not mentioned anywhere how these plates will remain firmly with the barrel when the beam is rotated at full speed during the warping process. Also not mentioned are the diameters of these plates and the length of yarn which can be stored on the beam. Flanges are also not shown in the diagram.

By the same group of inventors, another patent (49) has been applied in series which is further extension of the previous patent. The figure 2.29 below shows the arrangement as available from the patent.

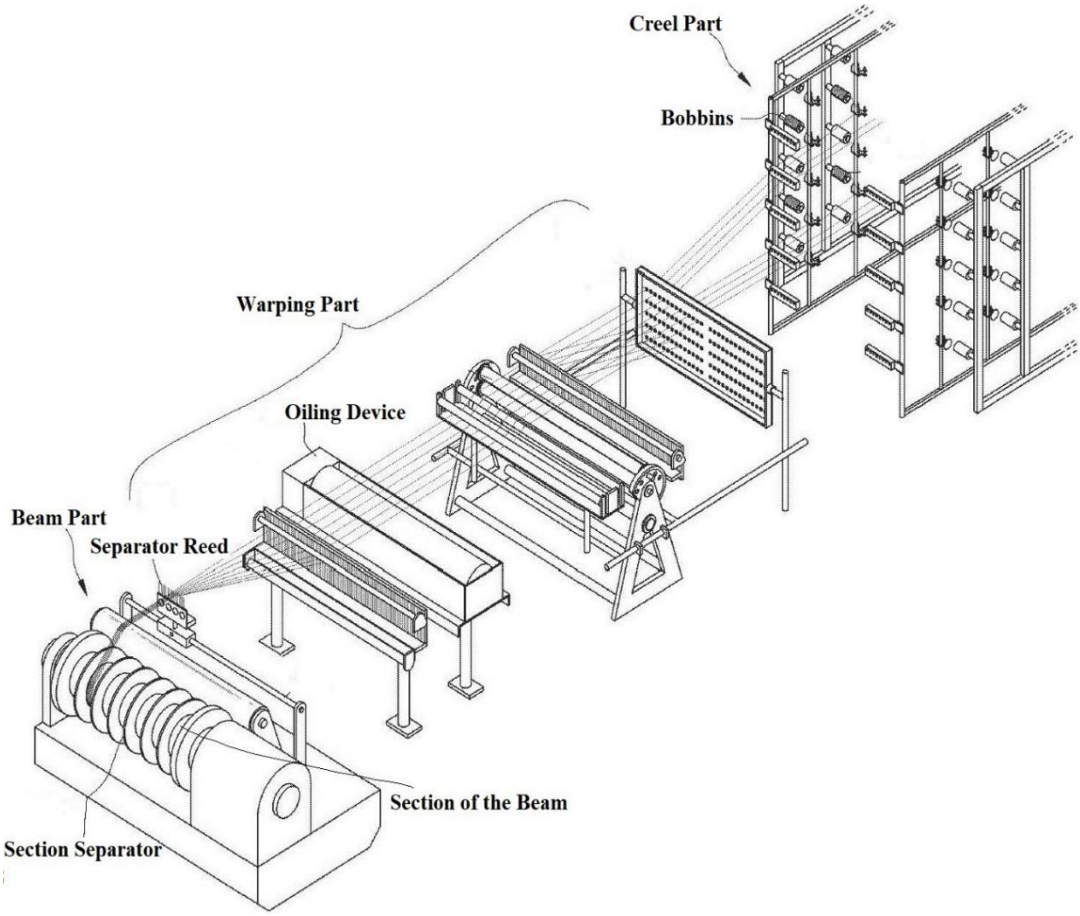


Fig 2.29 Arrangement for warping (49)

The invention claimed is mainly suitable for knitting or weaving process. There are six separator plates providing seven sections in the beam. In this invention there is brief mention about the adjustment of the width but not shown or explained the manner in which the same can be carried out.

The creel, tensioner, oiling unit, reed etc. are as used normally on any warping machine. The arrangements shown in various patent diagrams exhibit two methods of warping viz. sequential and simultaneous. As per the documentation it is claimed that the system is suitable for small creel size and more suitable for sampling operation.

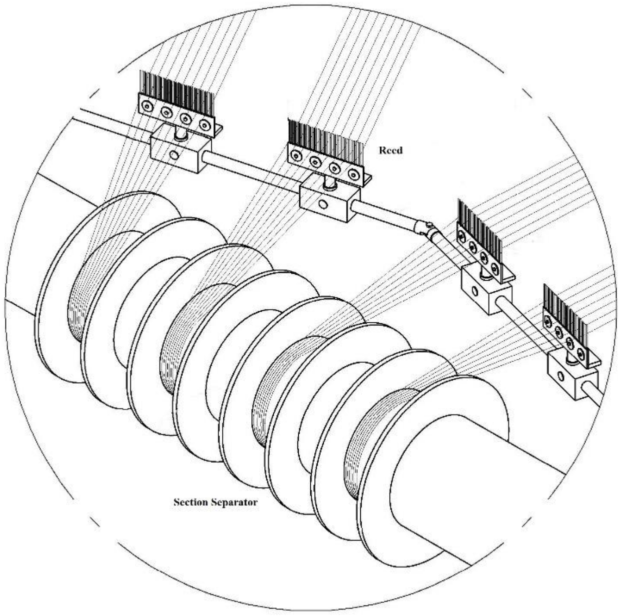


Fig 2.30 Close up view of the reed and section separator (49)

If the system is to be used for knitting beams then the simultaneous warping of few threads over all beams is possible. If it is to be used for warping then sequential method will be used. This means that the operation will be repeated for all sections using the same creel. The reed is mounted in parts or alternatively can be shifted in the manner to be aligned with the warp beam section. As per the diagram, there is large gap between two separator plates so the width has to be narrowed in the later on process. The close up diagram of the reed and section separator is as shown in figure 2.30. This is not a preferred method for warp preparation for weaving.

The patent has been filed in Republic of Korea and there are many versions of the same with different application numbers with various modifications. The invention provides an excellent idea about solving the problem of combining two systems of warping in to one but there are some questions which remain unanswered. As per the claim, the system cannot be used for warping but will be advantageous for preparing beams for warp knitting operations.

2.3.4.6 Dividable / Divisional Beams for creel efficiency

Lastly one very interesting patent filed by Kwang et al (50) will be discussed. This patent is little unique in many respects and will be considered as very close to the proposed work here.

The patent contains full design of the beams with all necessary diagrams. The background behind the invention has been written with elaboration. As per the patent literature, inventors have explained following problems with the current system of warping.

1. Due to ever changing specifications of the fabric, total number of ends in the fabric will also be different. This leads to lower utilization of creel capacity.
2. Due to above there are frequent creel changes leading to increased stoppage time.
3. As it is very difficult to have exact length of yarn on wound bobbins, there is problem of residual yarn leading to wastage and increased cost.

The inventors have mainly designed beams with small widths. Figure 2.31(a) below shows the normal beam and the narrow width beam. The narrow width beam is similar to normal beam in all respects otherwise.

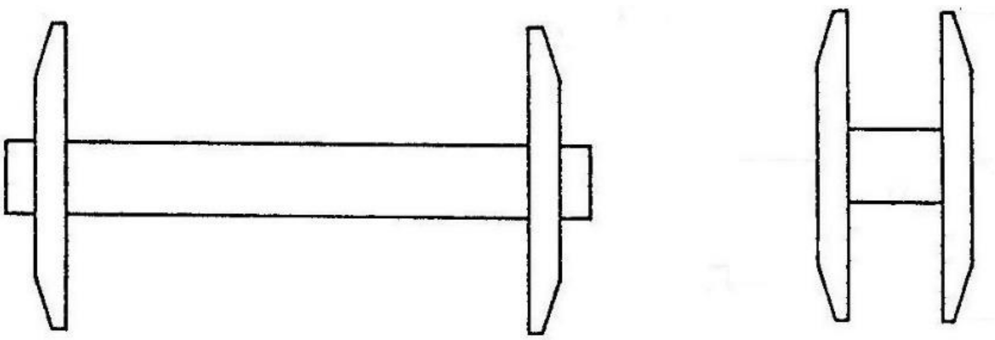


Fig 2.31 (a) Normal beam and narrow width beam (50)

It is possible to have same or variable width of all such beams. The figure 2.31 (b) shows both types of beams. All beams, with equal or unequal section widths, are attached on the barrel via locking mechanism organized at the end of each flange. The flanges are similar to the ones used normally on a warping machine. So the space occupied by each flange is quite large.

It is obvious that the main intention of the invention is not that of unifying two systems as each flange will occupy the space equal to several threads. This will lead to great problems of tension at the later on stages.

Figure 2.31 (c) below shows the way in which two types of reeds viz plain and zigzag are used during and after warping process. Again zigzag reed is as used normally whereas the plain reed is in to sections and is adjustable to suit the width of the beams.

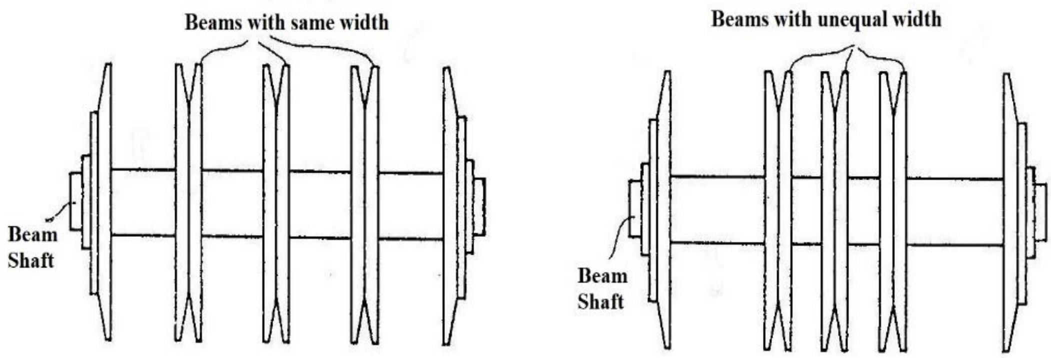


Fig 2.31 (b) Beams with same and unequal widths (50)

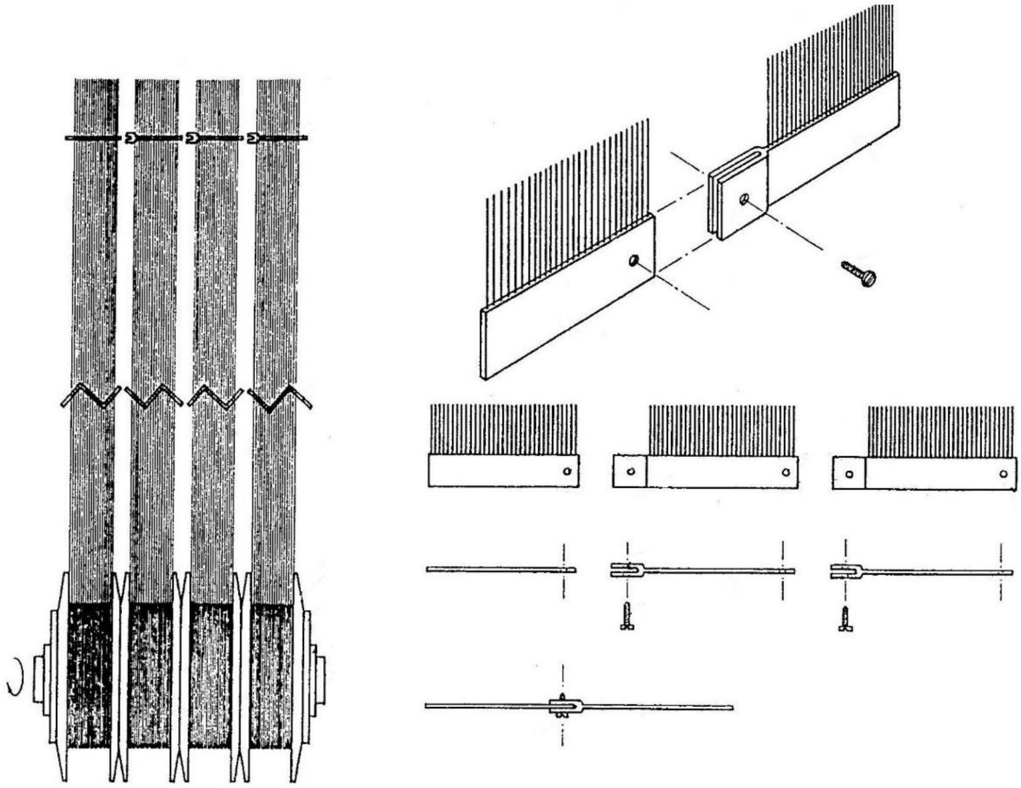


Fig 2.31 (c) Arrangement of Beams and reeds (50)

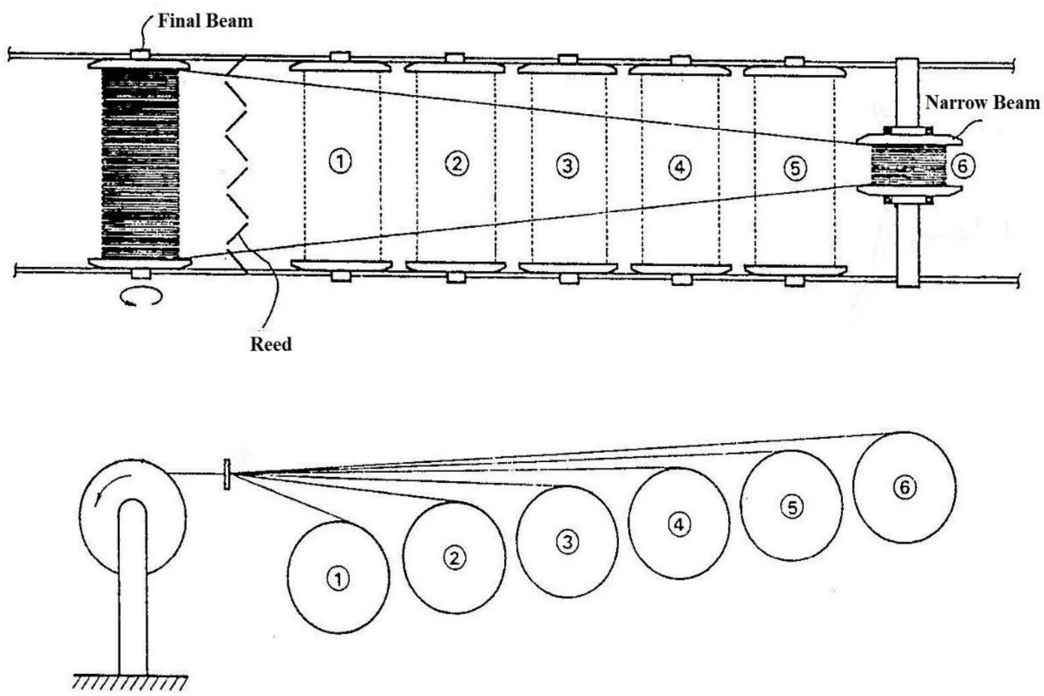


Fig 2.31 (d) Beaming operation (50)

Figure 2.31 (d) shows the final beaming operation. Here the arrangement shows all normal beams and one or more narrow width beams taken at the same time to get final weaver's beam.

The basic idea behind the invention is that of maximum utilization of creel capacity. Most of the time the creel is not fully utilized especially when patterned warp is to be run. For mono colored warp also it is not possible to fully utilize the creel as all beams are normally to be produced containing same number of threads. To encounter the situation and to increase creel efficiency, following equation has been provided in the patent literature.

$$E = N_m \times C_m + R, \text{ and also,}$$

$$R < C_m \quad \text{Where,}$$

- E - the total number of ends of a woven fabric
- N_m - the number of single large warper's beams used in one beaming
- C_m - the number of warp yarns wound on a single large warper beam, which number is identical or close to the maximum number of yarns provided on creel
- R - the number of residual warp yarns generated in one beaming, which yarns are assigned by the properly selected divisional warper's beam

So, first of all beams will be wound with maximum utilization of the creel. Depending on total number of yarns in a fabric, there will be no threads if the total ends are whole number multiple of creel capacity or else some threads will be left out. If threads are left out then the same will reflect in the equation above as value R which naturally is less than the capacity of the creel (C_m).

These threads will be wound on one or several narrow width beams separately as shown in figure 2.32 (d). This way it will be possible to utilize creel to the full extend and as per the claim made will lead to saving of the time also.

Following problems are still unexplained if we look at the whole design for single color situation. For that situation, organizing a separate narrow width beam will lead to many adjustments to be made at warping stage in terms of creel and head stock part. Also a narrow width beam may have a different tension value which may reflect as stripiness if the fabric is over dyed.

Another point is that of selvedge. Not much of the problem may arise if selvedge threads are same as body threads. But many times selvedge threads are different than body threads in which case they are to be taken separately for both sides. It is not clear from the document about how to organize the same with narrow beams and with the above equation. Also if selvedge threads are different, then creel utilization may not be full. If one resorts to changing bobbins after first beam (which contains selvedge threads of one side), then production loss will occur. Similarly the situation will occur for second side selvedge threads.

Over and above the problems discussed in the previous paragraph regarding single color beams, if we talk about the patterned warp beam then the whole equation needs many modifications because the creel utilization will depend on the creel capacity and the repeat size factors. Also remnants yarn may involve multi colored threads including selvedge threads.

How to adjust the pattern later on during rebeaming or sizing operation is also not discussed in the patent literature. So, the patent seems to be one more way in which the older form of tape warping may be used to solve the issue of increasing creel utilization efficiency.

The literature review carried out highlights following attempts:

1. In all of the published work in terms of books, journal articles etc., there has not been any mention about the way in which both systems can be combined. Most of the papers talk about process, production and quality control parameters and how they are or can be controlled with increased use of latest technology.
2. There are number of patents applied and registered regarding different ways in which the efficiency of the process can be increased and creeling time can be reduced. Also there are trials about making sections in the

beam so as to make the system adaptable for various yarns. Most of the attempts have one or the other limitation when it is required to run at full speed in the mill setting for mass production. There are attempts also to modify direct system or sectional warping system to make it flexible mainly in terms of increased productivity by reducing creeling time.

It will be worthwhile to note here that the translation of all the Chinese and Korean patents is as provided by the Google translation service. There are many genuine problems encountered in interpretation of most of the above patents. In all those cases final discussion is based on the diagrams available with the patent.

Hence it is required to make an attempt to find the solution to the problem of making a design of a system by which all kinds of yarns can be wound and there will not be need for two separate warping system.

In this work, a design of a model of the beam has been made which has unique features not seen previously. Also a three dimensional drawing of the same has been evolved to have full understanding. Secondary aim of the work is to make a prototype of the model using 3-D printer facility.