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TECHNO-ECONOMICS & ADVANCES OF SHUTTLE-LESS WEAVING TECHNOLOGY

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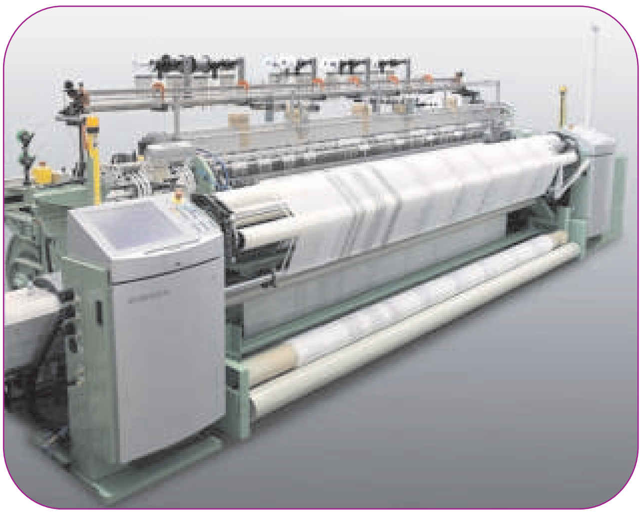
ABSTRACT: -
This paper is discussed about developments in shuttle-less machines with hope that, as a staunch advocator of modernization, awareness of developments would lead to critical analysis of machinery options, which in turn would help in selection, and implementation of right technology. Among shuttle-less machines considerable developments are observed in 3 basic picking principles, Projectile, Rapier and Airjet, while the new multiphase weaving developed by SULZER Co. and 3D-fabric manufacturing methods are worth discussing. A selective, noteworthy feature covering various machinery manufacturers and those that a professional should know for better understanding of the machines would be discussed.

KEYWORDS: *Shuttle-less weaving technology, 3D-Fabric manufacturing.*

INTRODUCTION

New developments in weaving have taken place in such a direction, which ensures reduced time, energy and cost involved. Heavy mechanical parts are now being replaced with electronic or microprocessor controlled alternatives. In the last two decades spectacular progress has been made in the field of weaving technology and the most significant being the replacement of convectional looms by shuttle-less looms for increasing productivity and quality of the end product.

Shuttle-less weaving is making an impact on the textile industry. The change over from fly shuttle to shuttle-less involves both new technology and shift from labour intensive to capital intensive, mode of production. Moreover, for export market, the quality requirements are becoming more and more stringent with the result that the export of the Indian mills is falling. Market demand is also for long lengths of fault free cloth, which is only possible with shuttle-less weaving machines. Increased labour cost without any corresponding increase in productivity is resulting in reduced profit to mill owners. So today, we are in need of shuttle-less machines which are weaving from the lightest to the heaviest of fabrics and diversified products using materials like spun, jute, woolen, worsted, metal wire, glass fire, mono and multifilament etc. with good quality.



We always said that

"We Required Good Quality Fabric!" but

"What Is Mean By Good Quality Fabric?"

SPECIFICATIONS OF QUALITY FABRIC:

- Width and length of the piece should be within acceptable limits.
- Fabric construction such as EPI, PPI, Warp count, Weft count, blend percent should be within limits.
- Fabrics should be free from contamination of color flaks, polypropylene, hair and jute or within specified limits per 100 linear meters.
- Tensile strength of the fabric should be as specified.
- Major defects such as floats, continuous missing end, wrong drawn-end, double end and double pick, visible to the eye should be absent.

LIMITATION OF SHUTTLE LOOM

Despite the relatively high speed and efficiencies in loom with conventional picking, productivity of these machines will continue to be limited as long as their fundamental constructions involved the use of shuttle propulsion. Vincent has shown that the power required for picking is proportional to the cube of the loom speed. If the loom speed is increased from 200 to 300 picks per minute, the power requirement would increase by a factor of (3/2)3 i.e. 3.4 times approximately. This results in following disadvantages

1. Greater strain imposed on the picking mechanism.
2. Greater amount of noise and vibration.
3. The movement of shuttle will be more difficult to control and there will be a greater possibility of its ejection from the loom.

DEVELOPMENTS IN SHUTTLELESS MACHINES

When the topic of developments in shuttle-less machines is discussed in any group/forum a question first arises is,

"Why Shuttle-less Machines?"

In-fact the modernization or automation is not just for reducing man power but also to increase the production of the fabrics as well.

The benefits of installing shuttle-less machines are as follows

1. Better and assured quality fabrics produced.
2. Higher rate of production.
3. Consistency and reliable performance.
4. Assured delivery time.
5. Flexibility of the machine.
6. Scope for manufacturing creative products.
7. Better-engineered fabrics, wider fabrics etc.

Productivity

The production rates of the various types of looms are presented for comparison

Table - 1 Production Rate of Various Types of Looms

Loom Type	Weft selection	Field of application
	Projectile Sulzer Ruti	
P7100	4 colours	Sheeting dress material filament weaving
P7200	4 colours	
STB Russia	4 colours	
	Rigid Rapier	
SACM	up to 4 colours	Yarn dyed fancy fabric manufactured such as Suiting, shirting smaller batch production
Dornier	up to 16 colours	
GUNNE	up to 6 colours	
	Flexible Rapier	
Somet	up to 8 colours	spun & filament dress material
Vamatex	up to 8 colours	
Sulzer Ruti	up to 8 colours	
Nuovo Pignone	up to 8 colours	
	Water Jet	
Metor SPA	Single colour	Weaving of filament,twisted & texturised filament sarees,dress materials
Nisson	Weft mix,1*1,2*2	
Tsudakom a	Weft mix,1*1,2*2	
	Air Jet	
Sulzer Ruti	up to 3 colours	Light gauge & sheeting,spun & filament fabric corduroy
Picanol Omni	6 colours	
Picanol Delta	2 colours	
Toyoda	6 colours	
Tsudakom a	6 colours	
Lakshmi Ruti	2 colours	

Table-2 Variety of Fabrics Woven on Specific Looms

Loom Type	Available width in cm	Speed in rpm	Weft insertion Rate(picks per minute)
	Projectile Sulzer Ruti		
P7100	190-540	320	1100-1200
P7200	190-540	430	1500
STB Russia	180-330	300	750
	Rigid Rapier		
SACM	150	550	1100
Dornier	150-400	460	1000
GUNNE	230	330	1200

Flexible Rapier			
Somet	165-410	550	1300
Vamatex	160-380	510	1300
Sulzer Ruti	110-280	325	1200
Nuovo Pignone	220-420	440	1000
Water Jet			
Metor SPA	230	1000	1600
Nisson	150-210	1000	2000
Tsudakoma	150-210	1000	2000
Air Jet			
Sulzer Ruti	upto 300	750	1600
Picanol Omni	190-380	800	1800
Picanol Delta	190	1100	2000
Toyoda	150-330	850	2000
Tsudakoma	150-340	1000	2200
Lakshmi Ruti	190	500	1200
Dornier	430	600	2520
Linear Multiphase			
Elitex	About 190	1100-1600	2000-3000
Drum type Multiphase			
Sulzer M8300	190	3230	6088(Plain)
	170	2430	4118(Twill)

Today the market particularly demands wide variety as much as possible at the lowest possible cost. These machines provide the feature such as:
- The possibility of weaving more difficult products in terms of yarn employed and also in combinations.
- Application potential in all weaving sectors.

FEATURES COMMON IN ALL MACHINES: -

Several essential features found common with all shuttle-less machines are listed below

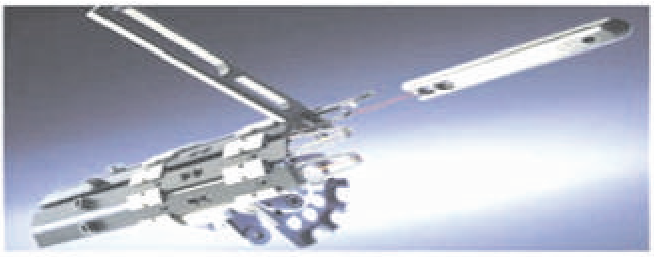
- Higher speed
- Wider width.

- Electronic take-up and let-off.
- Shedding systems- cam , dobby and jacquard (mechanical and electronic).
- Electronic monitoring of weft yarn flight.
- Electronic warp stop motion.
- Automatic pick finding.
- Quick style change.
- Microprocessor controls with digital display.
- Low noise and vibration.
- Tension free weft supply by weft accumulators.
- Microprocessor control lubrication system.
-

DEVELOPMENTS IN PROJECTILE MACHINES

1) Colour Selection: -

- 1 X 1, 2, 4 and 6 coloursS can be used in weft direction.
- The system is freely programmable and operated by servo controller.
- No limitations on feeder position shifting.



Original feeder and projectile grippers from the wide Sultex range help ensure high efficiency and perfect fabric quality.

2) Electronic Weft Braker: -

- This device keeps a uniform tension on weft.
- The braking force and the braking duration are programmable.
- Program can be given for each pick.
- The device is driven by stepper motor.

3) Pre-acceleration to weft yarn is given by compressed air, which relieves extra tension in weft while inserting.
4) K3 Synthetic projectile can be used for weaving of delicate yarns.
5) The no. of heald shafts operable by cam motion is extended to 14.
6) Speed has been increased upto 1400 mpm (470 rpm). Due to improvement in many related mechanisms.
7) LED display at signal pole for machine speed, projectile arrival time, angle of machine stop, etc. which helps in monitoring of process.
8) Automatic weft brake repair motion enables shifting of feed package to a reserved one in the event of weft break between package and accumulator, no stopping of machine which increases the machine efficiency.

DEVLOPMENTS IN AIRJET WEAVING: -

The Airjet weaving machine continues to dominate as the machines of very high speeds. Today, practically (an Indian condition) at 1200 rpm the machine works or wider machine can attain a WIR of 2500 mpm. The system had the disadvantage of higher energy consumption due to the usage of compressed air in picking which accounts for 60% of total energy consumption.

The machine makers claim a reduction in energy by about 10% (Sulzer, Somet) in their latest models. The developments in picking related systems have helped in expanding the horizon of weft material and count. The yarn colour selection upto 6 or 8 beyond which demand is very rare. That means, the major limitations of the system are being attended and scope for applicability has been increasing.

LATEST DEVELOPMENTS: -

Modification in Weft Insertion System: -

The multi nozzles are divided into two zones and connected directly with separate tanks. The weft yarn requires higher pressure at later part of its flight, and this separation has helped greatly in optimization of pressure in duration of Jet opening.

- The weft insertion, based on a precise electronic control that includes ATC (automatic timing control), also uses newly developed nozzles, which guarantees optimum weft insertion conditions.
- Independent pressure tanks make it possible to set weft insertion pressures at optimal levels, this makes a significant contribution to energy conservation.
- All settings regarding picking is done by microprocessor keyboard, which reduces machine down time.

❖ Tapered Sub-Nozzles: -

It consists of a tapered hole to prevent air dispersion.

Advantages: -

a. It enables stable weft insertion with lower air volumes.
b It stabilizes air injection angles during weft insertion.
c. The weft insertion is more stable and requires less air.

❖ Tandem Nozzles: -

In tandem nozzles, the two main nozzles are arranged in series so called tandem nozzles.

Advantages: -

a. It reduces the nozzle pressure
b. Saving in energy
c. Also use of wider weft count range.
d. Low pressure weft insertion to occur, making effective for super high-speed operation accommodating yarns with low breaking strength.

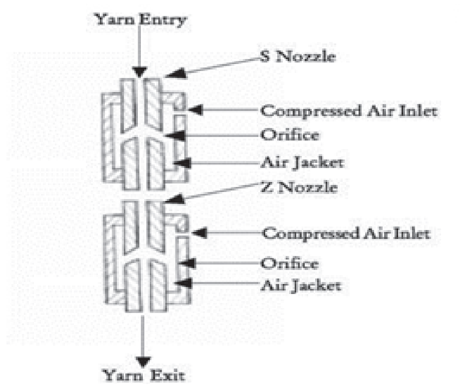


Figure 2 Twin air-jet nozzle arrangement

❖ Tapered Tunnel Reed: -

A tapered shape has also been applied to the tunnel selection of reed blade.

Advantages: -

1. It helps in preventing air dispersion.
2. The weft insertion is more stable and requires less air.

❖ **Electronic Braking System: -**

One of the serious drawback of Airjet picking was tension peak in weft when brake is applied. The electronic braking system can precisely control braking time and brake stroke, which significantly reduces tension pick, thereby reduction in weft breaks.

❖ **Automatic Pick Controller: -**

For smoother working, all machines have weft arrival time sensing and correction of pressure at nozzles but when package is changed from empty to full package, the arrival time will be delayed and this would be beyond the capacity of such a correction system. With APC (Automatic pick controller), this problem is attended.

- It instantly corrects the main nozzle's air pressure for timing control during full cheese changes.
- It adjusts automatically nozzle air jet pressure, which compensates for variations in the travel timing of weft yarn.

OTHER DEVELOPMENTS: -

- Weft feeder threading is comparatively time consuming and, now the self-threading by pneumatic system is done.
- The weft cutter is electronically controlled and operated by steeper motor By this, cutter can easily adapt to any cutting time to the accuracy of 1°. Style changing time is saved.
- With the help of mechanopneumatic tucking device can hold the weft at both selvedges firmly during beating and then tuck-in. this eliminates auxiliary selvedge and weft waste is zero. The system can work upto 850 rpm.
- Almost every machine manufacturer supplies positive easing motion for maintaining constant tension during shedding and beating.
- There is a new shedding concept introduced, in which the heald shaft is directly controlled by Servo Motor. Thus the total motion of heald shaft can be independently programmed.

DEVELOPMENTS IN RAPIER WEAVING: -

The Rapier machines are emerging as weaving machines of the future. They are not far off from Airjet in production (Speed) rate (upto 1500mpm or 600 to 800 rpm) without scarifying their special status of flexibility. They have been making inroads to heavy fabrics (900 gsm) and also shedding off the known drawback of higher weft waste.

SPECIAL DEVELOPMENTS: -

The design improvement in Rapier gripper permits handling wide range of yarns without any need for changes.

The machine owes its speed, flexibility and low energy consumption to a combination of high technology and economic design. Style changes can be executed 'Exceptionally rapidly'. having independent motor drives, this yielded fewer moving parts, fewer gears, fewer oil seals and no timing belts i.e. there are fewer elements to influence fabric quality, less need for resetting and reduce maintenance. There are no toothed belts, which are prone to wear, and breakage.

The right choice of yarn clamps, correctly adjusted, prevents Cost-intensive Machine stoppages and increases productivity.

SUMO MOTOR

- Saving on energy consumption of more than 10% in comparison with conventional clutch and brake configuration.
- Machine speed setting is done accurately and completely, electronically via the keyboard of microprocessor. This reduces the setting time to zero.
- Speed setting is easy to copy to other machine either with electronic set card or with production computer with bi-directional communication.
- Automatic pick finding becomes faster, which significantly reduces the down times for repairing filling and warp breakages.
- The machine can always work at optimum weaving speed in function of quality of the yarn, the number of frames, and fabric construction.

PFL (Programmable Filling Lamellae): -

It controls the filling brake ensures a current yarn tensions at any time during insertion cycle. The PFL can be installed for each channel between the pre-winder and entry of fixed main nozzle. It has been designed to slow down the filling at the end of insertion. The PFL thus significantly reduces the peak tension of the pick at the end of the insertion and decrease the tendency of pick to bounce back in the shed. As a result of which the filling tip is stretched correctly.

FEATURES: -

- Lower peak tension in filling yarn.
- Reduced tendency of filling to bounce back.
- Inserted pick can be stretched more easily.
- Adjustments are done by means of machine keyboard and display.
- The settings can be adopted for each filling yarn.

BENEFITS: -

- Fewer filling breaks.
- Fewer machine stops.
- Better fabric quality.
- Higher productivity of machine and staff.
- Weaker filling yarn can be used.
- Correct setting of filling waste length and consequently less waste.

QSC (Quick Style Change): -

With quick style change just one person can carry out a style change in less than 30min. This is achieved by swapping the whole back part of split frame, with the warp beam, the back rest and the supports, the warp stop motion the harness and the reed.

Additionally this unique system makes it possible to carry out all article related settings on the warp side outside the weaving shed, before the style change, QSC not only reduce labor requirement but also result in efficient planning of warp and style changes. The key to the operation is the split frame design; several extra modules and warp modules transporter are also required.

FEATURES: -

- Reduced machine down time.
- Interference losses due to simultaneous stops are practically non-existent.
- Fewer personal required for warp and article changes in weave room.
- Warp changes can be replaced by style changes, enabling the load on the tying and drawing-in equipment to be balanced instead of having two bottlenecks.

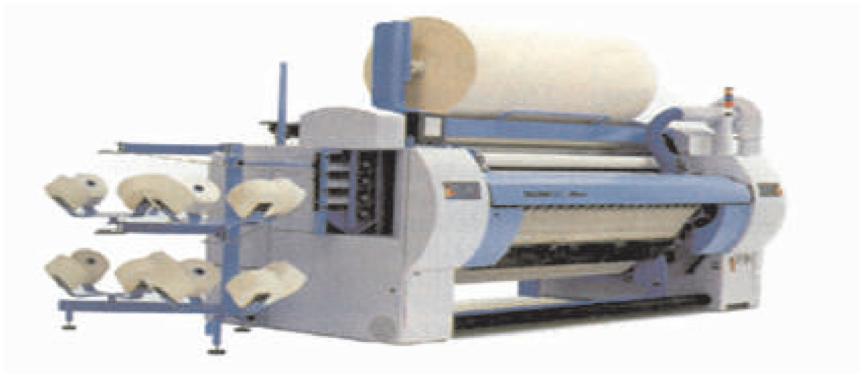
ELECTRONIC TAKE-UP AND LET-OFF MOTION: -

It plays important role. Required pick density can be programmed on microprocessor keyboard. No pick wheel required. The accuracy of settings make it easy to adjust pick density of fabric with optimum fabric weight and minimum yarn consumptions. By ETU make it possible to weave fabric having various pick densities.

The electronic link between let-off and take-up is an additional tool to manage the fabric marks. Warp beam driven by electric let off motion through separate drive wheel that stays on loom, ensures trouble free operation of let-off system and improve fabric quality.

MULTIPHASE WEAVING MACHINE: -

The Sulzer Ruti M8300 Multiphase weaving machine has introduced a new concept to the principle of multiphase weaving. The phase wise shed formation is along the warp direction instead of weft direction and 4 weft yarns are inserted simultaneously.



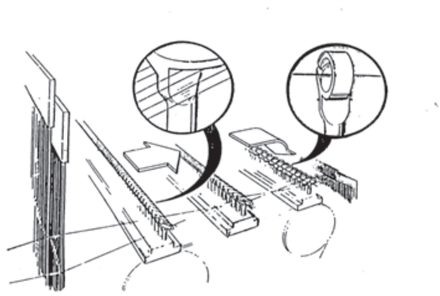
Sulzer Ruti M8300 Multiphase weaving machine

FEATURES: -

Shed Formation: -

The warp yarns pass over rotating weaving rotor and shed forming elements select and lift warp yarn for shed formation.

The curve shape of the elements, rotation of rotor and movement of warp positioner help in selection and formation of shed by controlling the motion of warp positioner. The weave selection is made possible.



Weft insertion: -

The channel in the shed forming elements guide in insertion of weft. The weft is inserted by nozzles are similar to Airjet weaving. Additional nozzles between shed forming elements further support the weft. Four wefts are inserted at a time. The weft measuring, clamping, cutting, sensing and controlling are similar to air jet machines.

Beat-Up: -

The combs located behind shed forming element perform the function of conventional reed. The lower shed, which rises after insertion of weft, lift the weft out of channel over the entire weaving width. The beat-up comb then catches the weft and beats up.

The modular design concept adopted has helped to change warp beam within 20 min. the warp beams upto 1600mm diameter can be used. The inclusion of batching motion for cloth winding has reduced change intervals.

Many machines are in operations since 1997- 98 and this might be the machine for mass production in future.

3D-FABRIC MANUFACTURING METHODS

The technical textile product can be used in three different ways:

1. It can be a component part of another product and directly contribute to the strength, performance and other properties of that product, e.g., tire cord fabric in tires.
2. It can be used as a tool in a process to manufacture another product, e.g., filtration textiles in food production, paper machine clothing in paper manufacturing.
3. It can be used alone to perform one or several specific functions, e.g., coated fabrics to cover stadiums.

The characteristics of 3D spacer fabrics are multifaceted. It is an extremely light material. An expected advantage of spacer fabrics is the freedom to orientate selected fiber types and amounts to accommodate the design loads of the final structural component. The main goal of thesis exists in the development of the weaving machine and structure elements of 3D-spacer fabric for lightweight composites. Therefore, this thesis spots the light on two important points which had been development of the let-off and take-up method on the weaving machine and also development of spacer fabrics structures. The importance of woven spacer fabric exists in using it as composites in the lightweight constructions.

In 3D-fabric structures, the thickness or Z-direction dimension is considerable relative to X and Y dimensions. Fibers or yarns are intertwined, interlaced or intermeshed in the X (longitudinal), Y (cross), and Z (vertical) directions. For 3D-structures, there may be an endless number of possibilities for yarn spacing in a 3-D space.

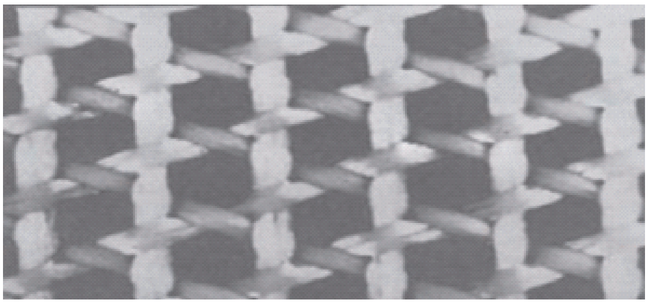
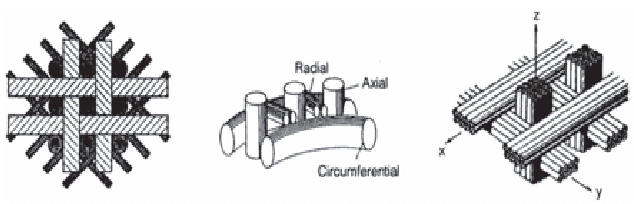


Fig: - Triaxial weaving

3-D fabrics are woven on special looms with multiple warp and/or weft layers. Fig. shows various 3D-Woven structures. In polar weave structure, fibers or yarns are placed equally in circumferential, radial and axial directions. The fiber volume fraction is around 50%. Polar weaves are suitable to make cylindrical walls, cylinders, cones and convergent-divergent sections. To form such a shape, prepreg yarns are inserted into a mandrel in the radial direction.



5-Direction construction Polar weave Orthogonal weave

Fig. Schematics of various 3D-woven fabric structures for composites

Except for the components that are fundamentally Cartesian in nature, orthogonal weaves are usually less suitable for net shape manufacturing than the polar weaves. Unit cell size can be smaller than polar weaves which results in superior mechanical properties. Since no yarn interlacing takes place in polar and orthogonal structures, they are also referred to as ´´nonwoven 3-D`` structures in the composites industry. However, it is more proper to label these structures as woven structures with zero level of crimp.

In angle interlock type of structures, warp (or weft) yarns are used to bind several layers of weft (or warp) yarns together as shown in Fig.. In place of warp or weft yarns, anadditional third yarn may also be used as binder. Stuffer yarns, which are straight, can be used to increase fiber volume fraction and in-plane strength. If the binder yarns interlace vertically between fabric layers, the structure is called orthogonal weave.

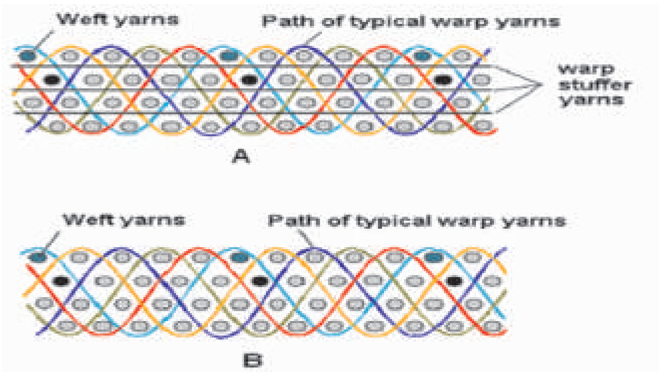


Fig: - Angle interlock fabric; (A) with and (B) without added stuffer yarns

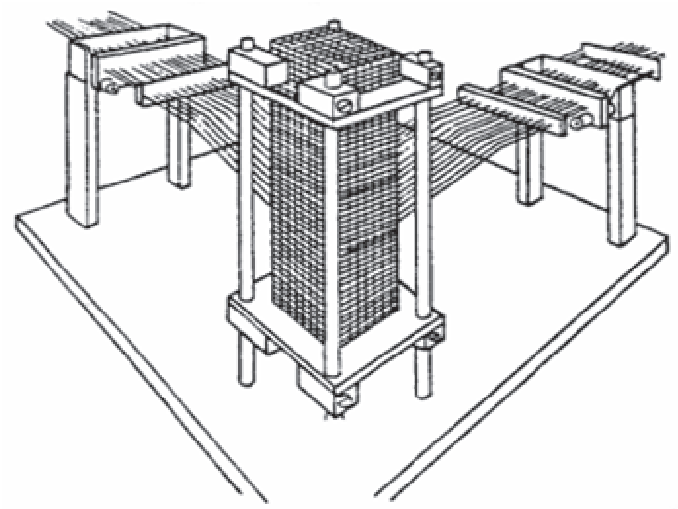


Fig: - Schematic of King's 3-D machine

Angle interlock or multi-layer fabrics for flat panel reinforcement can be woven on traditional looms, mostly on shuttle looms. The warp yarns are usually taken directly from a creel. This allows mixing of different yarns in the warp direction. Other more complex 3D-Fabrics such as polar and orthogonal weaves require specialized weaving machines. Several weaving machines were developed to weave complex 3D-structures as illustrated in Fig. Multilayer weaving into a three-dimensional preform consists of interlocking warp yarns in many layers. Whereas in conventional weaving all of the warp yarns are oriented essentially in one plane, in the structure.

CONCLUSION: -

Many times in the past it was argue that Projectile and Rapier systems have attained maximum speed limit. However, these machines continue to enhance the speed limit and are not far behind Air-jet machines. Most of the developments are in the area of attaining better fabric quality, gently treatment to warp and weft and reduce breakages. Another interesting trend in the type of selvedge formation and waste reduction. Weft waste has been reduce to zero even in Rapier and Air-jet machines.

However, the economy of this type of loom lies with its increased weft insertion rate per unit floor space and reduced energy consumption during selection process. It shows great promise for further scale up of the innovative weaving machine for commercial trials.

The further trend in developments would, probably, be in similar lines. However, one cannot rule out some surprising, thrilling innovations like Sulzer M8300 type multiphase weaving machines.

However, new indispensable 3D-fabric manufacturing methods, which have been primarily devised to organize and assemble essentially three orthogonal sets of yarn in the fabric-length, -width and thickness directions, has not been a matter of examination from the point of textile technology. T he use of sandwich structures is growing also very rapidly around the world. It's much advantage, the development of new materials and the need for high performance, low weight structures insure the sandwich construction will continue to be demand.

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