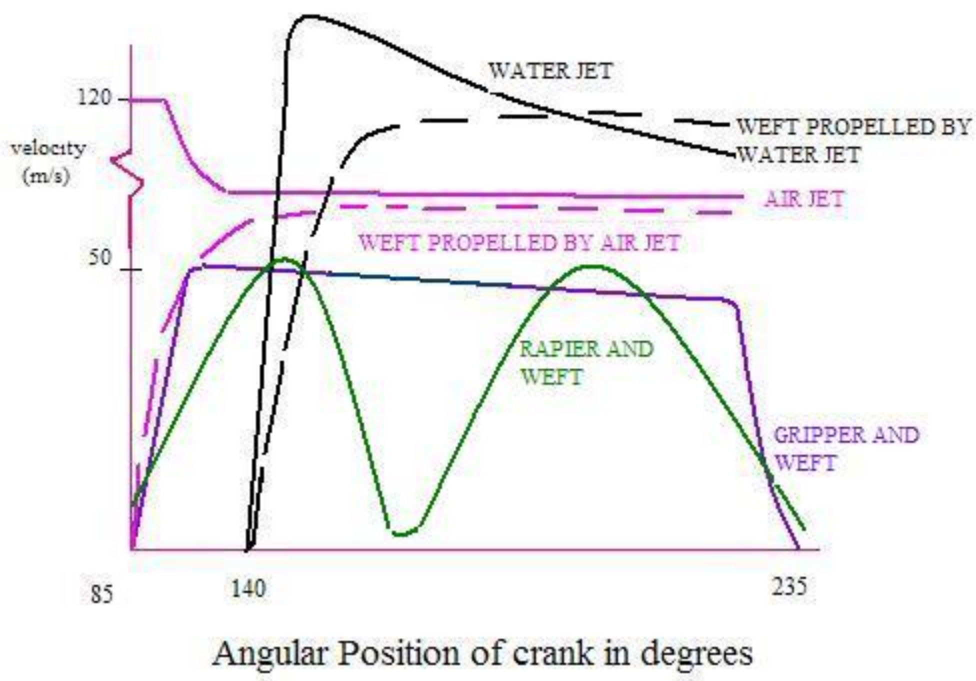
Section 3
FAQ

1. Plot to scale typical velocity profiles of weft and the weft carrier as function of flight time of the shuttleless weft insertion systems.

Ans



2 The following are given for a gripper shuttle loom

- Mass of gripper = 0.04 kg
- Shear rigidity of torsion rod = 8163. 10^7 N/m^2
- Length of torsion rod = 0.72 m
- Polar moment of inertia of torsion rod = 5.10^{-9} m^4
- Maximum angle of deformation of torsion rod = 0.5 radians

Calculate the maximum velocity that the gripper may attain if the entire energy of torsion rod is transmitted to the gripper. What are the mechanical constraints to achieving a high percentage of energy utilization?

Ans Toque generated in the rod is expressed by

$$M_t = K_{t.}\,\varphi = (\pi.d^4.G).\varphi / 32.\ell = (E.G).\varphi / \ell$$

Where E= Polar moment of inertia

G =Shear rigidity

Φ =Angular deformation

And ℓ= length of rod

If the rod is assumed to be linearly elastic then torque generated would grow proportionately with angular deformation of rod and the plot of torque as function of angular deformation would be a right angled triangle. Area covered by this triangle would represent potential energy stored in the rod and can be expressed as

$$P.E. = [(E.G).\varphi / \ell].(\varphi/2) = [(E.G)/\ell].[\varphi^2/2]$$

Substituting the values in the equation

$$P.E. = \{[(8163.10^7) \times (5.10^{-9})]/0.72\} \times \{0.5^2/2\} \text{ N. m}$$

If this entire energy gets converted to kinetic energy of gripper, then

$$(1/2).(0.04).(v^2_{max}) = P.E.$$

Or $v_{max} = 59.5$ m/s

The constraints to achieving a high conversion rate of P.E. of torsion rod into K.E. of gripper are inertia and natural frequency of picking lever, inertia of gripper and the dissipating forces such as friction and air resistance.

3 Compare the mechanics of conventional shuttle propulsion with that of gripper shuttle propulsion.

Ans Both conventional shuttle propulsion and gripper propulsion are based on development of strain energy in respective picking mechanism and its release to the weft carrier. In case of conventional shuttle propulsion the generation of strain energy and its gradual release is simultaneous whereas in the latter the two functions are executed with a phase difference. This fundamental difference in generation and transmission of picking energy in conjunction with a much lower mass is instrumental in much higher value of average acceleration and consequently much higher initial velocity in flight of up to 50 m/s for projectile as compared to a maximum of 15 m/s for a conventional shuttle.

4 For a 1.5 times rise in duration of passage of weft thread and a ten times lower mass of weft carrier, by how much could the WIR of a gripper loom be higher than that of a shuttle loom if the picking power is held constant.

Ans Power of picking is proportional to $[m. n^3/\theta^2]$, where m=mass of carrier, n=loom rpm and θ=the angular displacement of crank during which carrier passes through shed. Accordingly under the given conditions

$$[m. n_1^3/\theta^2] = [(m/10). n_2^3/(1.5\theta)^2]$$

Or $$[n_2 /n_1]^3 = 22.5$$

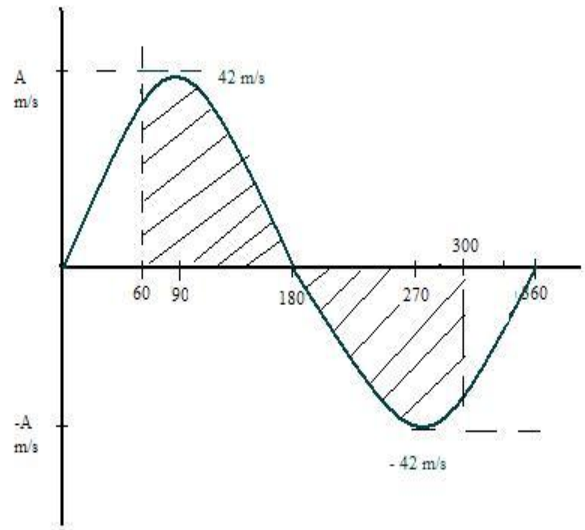
Hence $$[n_2 /n_1] = 2.823$$

Thus under the changed condition the WIR can go up by 2.823 times.

5 Draw to scale the velocity-time diagrams of weft being inserted by Dewas and Gabler types of rapier assuming

- The WIR to be 1200 m/min for a 3m wide loom
- Rapiers remain in shed for two thirds of a cycle executing simple harmonic motion

Ans Loom rpm for a 3m width and 1200 m/min WIR is 400.
Hence time for one loom cycle is [60/400] s = 0.15 s
Rapier remains in shed for 2/3rd of loom cycle which therefore takes 0.1 s
Hence the average velocity of rapier in shed is 30 m/s
If rapier executes SHM then it enters the shed at 60^0 crank position and leaves shed at 300^0 crank position.
Overall velocity profile of rapier is given by s = A sin θ, where θ is the angular position of crank
Average velocity of rapier during its movement in shed is $[3/2\pi] \int A \sin\theta_{\,[\pi/3 \text{ to } \pi]}$
$= [3/2\pi] [A \cos (\pi/3) – A \cos (\pi)] = [3/2\pi]\ 1.5A = 4.5A/2\pi$
Hence average velocity is 0.72 times the maximum velocity
Hence the maximum velocity is 1.39 times the average velocity = 1.39 x 30 = 41.7 m/s

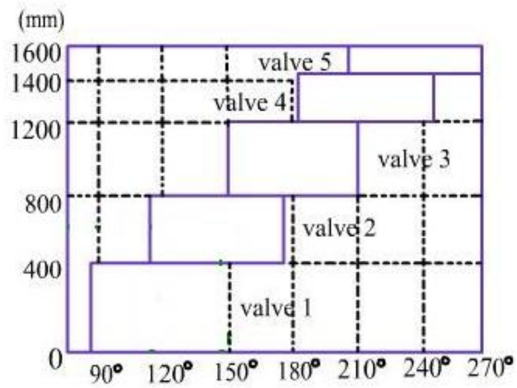


Both Dewas and Gabler rapier inserting a single pick would exhibit the same velocity profile.

6 Why rapier looms operating with tip to tip transfer principle are more suitable for production of complex fabrics as opposed to other forms of weft insertion systems? Would this hold true for loop transfer systems as well?

Ans With a tip to tip transfer system the weft is gripped only at its tip, leaving rest of the weft body completely untouched by the carrier. Air and water jets apply drag force on a weft along its entire body while in a loop transfer system a vigorous rubbing takes place between rapier head and weft thread. A gripper also grips only the tip of weft and does not have any effect on the body of weft. However the impactual shock that a weft is subjected to while getting accelerated as also a possible whiplash effect during braking of gripper subjects the weft to another type of high strain. A similar kind of strain is also subjected by jet streams. Weft tension profile during rapier insertion can however be controlled and maintained at a moderate level as per properties of weft yarn. Thus complex fabrics employing weft threads of various materials are preferably woven on rapier looms employing tip to tip transfer system.

7 Consider the blowing profile of relay jets shown in the diagram below and calculate (a) the air consumption per loom cycle and (b) the range of yarn length under influence of the jets during one cycle if WIR of the loom = 960 m/min and the relay jets are spaced 100 mm apart, each blowing 6 liter of air per minute of operation.



Ans Number of jets controlled by each of the valves 1, 2 and 3 is four, whereas each of the two valves 4 and 5 control two jets. Thus there are in all 16 jets. The loom runs at 600 rpm completing one cycle of operation in 0.1 seconds. Each of the five valves operate over 60^0 of crank shaft rotation which takes (1/60) s. In other words each of the 16 jets blows for (1/60) s accounting for a cumulative blowing time of (4/15) s. Thus air consumption per loom cycle amounts to (400/15) = 26.66 cc.

Just at the point of switching-off of the first valve, a length of 800mm of weft was under action of jets of the first two valves whereas this value dropped to 400 mm just beyond this point. This pattern continues till the weft tip reaches 1400 mm reed space at which point the valve 3 is switched off and the valve 5 is switched on. Length of weft under influence of jets of the fourth valve is only 200 mm. This value grows to 400 mm as and when the weft tip reaches 1600 mm reed space. However after 240^0 crank position, this value drops to 200mm again.

8 An air jet machine of width 4m operating at 650 rpm has 10 relay jets per meter of reed width. The weft yarn takes 150 degrees to cross the entire reed width and the relay jets blow over a period of 180 degrees of main shaft rotation. If 100 cc of air is blown by each jet per second and if a minimum length of 250 mm of weft yarn has always to be under the influence of air jet then work out the total air consumed by the valves controlling the relay jets in a shift of 8 hours at 98% loom efficiency, if a distribution of 2 jets per valve is assumed over the entire reed width.

Ans Each jet covers 100 mm and therefore each valve would cover 200 mm. Foe crossing a distance of 200 mm the weft yarn consumes 7.5 degrees of crankshaft rotation. The first valve has to keep on blowing even after yarn tip has crossed over into the zone of influence of second valve. It can switch off only when the 3^{rd}

valve has switched on and yarn tip has crossed 50 mm of the zone under influence of third valve, ensuring that a minimum length of 250 mm of yarn remains under influence of relay jets. Hence the first valve operates for (7.5 x 2) + (7.5 / 4) = 15 + 1.875 = 17. 875 degrees of crank shaft rotation. This would hold true for the next 18 valves. The 20th valve would blow for (7.5+30) = 37.5 degrees. Thus the 20 valves would blow for a time equivalent to a total of (19 x 17.875) + 37.5 = 370 degrees. For a machine running at 650 rpm, a 1^{0} crank rotation takes 2.56 x 10^{-4} seconds. Hence total blowing time of 20 valves is [2.56 x 10^{-4} x 370] = 0.09487 s. As each valve controls 2 jets and each jet blows 100 cc of air per second, total air blown by relay jets per loom cycle is 0.09487 x 200 = 18.974 cc. Over one entire shift the total consumption would be [8 x 60 x 0.98 x 18.974 x 650 x 10^{-3}] = 5,800 liters = 5.8 m^3 of air.

9 Assuming that a 3m wide air jet loom is equipped with 42 relay nozzles controlled by 11 valves work out the blowing sequence of different valves for an optimal performance. Find out the periodicity of variation in length of yarn controlled by the jets.

Ans Considering uniform spacing of relay nozzles, a gap of 72 mm exists between successive nozzles. Each of the first ten valves would thus supply air to a group of four nozzles, accounting for about 288 mm of reed space. Hence the lowest value of yarn length under influence of relay jets at any instant would be 288 mm. This statement holds true after the weft tip has gone past the fourth relay jet. As yarn would always be under influence of jets blown by at least one valve and at most by two valves, the upper limit of yarn length under influence of jets would be (288 x 2) = 576 mm.

10 Would the air consumption of an air jet loom weaving cotton yarns be

- Greater for finer yarns?
- Less for highly twisted yarns?

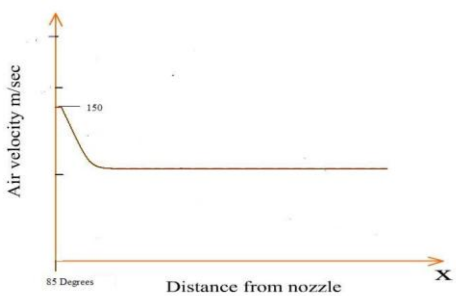
Justify your answer.

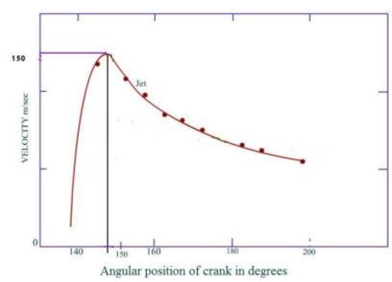
Ans Consumption of air depends on drag force that develops between yarn and air jet. This force is higher for greater yarn surface. Both a finer yarn and a highly twisted yarn would offer lower surface area to the jet stream than otherwise. Therefore air consumption in both cases would be higher.

11 Considering the sectional view of a jet nozzle explain how the pressure energy of air gets converted to kinetic energy. Under what condition does the tip of weft get sucked into yarn tube?

Ans Consider Figs. 13 and 14, showing respectively a Venturi tube and a typical sectional view of an air jet nozzle. Assuming laminar flow and implicitly a constant fluid density, the mass of fluid moving through the larger section at a certain rate has to move through the narrower section also at the same rate and hence its velocity in the narrower section must go up. Bernoulli's equation predicts that a rise in velocity would be accompanied by a drop in pressure. By suitably designing the nozzle it is possible to bring down the fluid pressure to sub atmospheric level. This sub atmospheric pressure at the tip of yarn tube creates a suction force which pulls weft from supply package into the jet stream.

12 Plot typical velocity profiles of a water jet and of an air jet emerging from the main nozzle as function of angular displacement of the main shaft. Indicate the values of approximate crank angle at which maximum velocity is realized in each case. Explain the reasons behind dissimilarities between the two plots.





Ans A jet of air comes out of nozzle at around 85 degrees with its highest velocity and then loses energy over a distance after which its velocity is boosted to a steady value by the relay nozzles. Approximate values of velocity estimated for a 2000 m/min WIR machine has been indicated in the figure shown above. In view of its much higher density and hence higher cohesive force, a water jet particle coming out of nozzle exhibits a much lower velocity. After escaping the drag imposed by inside wall of nozzle mouth the water jet particles accelerate rapidly reaching the maximum velocity at about 150 degrees of crank position.

13 Explain the reasons behind the following observations

- A modern gripper loom exhibits a much lower WIR but much higher maximum possible reed width as compared to a modern jet loom
- The tip of water jet emanating from a nozzle exhibits a fist like bump during its motion beyond the laminar zone

- The rapier system of weft insertion is preferred for weaving fabrics requiring a wide range of weft yarns – in terms of count and material – in the same fabric
- The peak weft tension in a jet loom is recorded when the tip of weft nears its end of flight path
- Dewas system of rapier is more popular than Gabler

Ans Inertia of a gripper as also its dimension are limiting factors to increasing projectile loom rpm while the difficulty in maintaining a sufficiently high air drag on weft over a very long distance limits maximum possible reed width on air jet loom.

Water particles coming out of nozzle exhibit a progressively higher initial velocity over a certain period of the jetting process (Fig 29). As a result particles coming out earlier are pushed from behind by particles following them. During a very brief laminar zone the jet stream behaves as a continuum but just beyond this zone water particles start forming into individual entities exhibiting their own velocity profiles. As a result of this pushing from behind and overtaking by particles that came out later, the smooth stream assumes the shape of a fist like bump.

Rapier propulsion system is positive in nature as a result of which motion of rapiers can be designed to follow a certain specific function, depending on nature of weft being handled. This aspect is illustrated in Fig 11. The ability to select and impart the most appropriate velocity profile to weft characterizes the essence of rapier propulsion system. This facility permits insertion of picks of diverse nature during the course of weaving. As no other propulsion system is positive hence rapier system is preferred for weaving fabrics with a wide array of weft yarns.

The rapier heads of Dewas system grip a pick of weft at one point only, somewhat in the manner of a gripper shuttle. They inflict no further physical damage to rest of the inserted pick. On the other hand rapier heads of Gabler system subject weft yarn to vigorous abrasive strain, both during insertion of loop into shed centre as well as during unfolding of loop over the other half of warp shed. Hence the Gabler system is unsuitable for most weft yarns as these yarns are by nature weak and soft.

14 Compare the relative merits of the four types of shuttleless looms in respect of

- Power consumption in kWh/kg of fabric produced
- Maximum possible reed width
- Control on weft tension during its insertion

Ans. Considering the table in section 13 it is observed that air jet looms consume highest power (3.2 units) followed by rapier (2.5 units), gripper (1.3 units) and water jet (0.9 units). Air compressor of an air jet loom that supplies air to a large number of jets consumes most of the 3.2 units. Overcoming the inertia and passing through repeated phases of acceleration and deceleration of rapier heads and their driving systems within each cycle of machine operation results in the high power consumption of rapier machines. The inertia of gripper being comparatively less and the fact that it is accelerated once and then decelerated after completing its free flight leads to a much lower power consumption. Indeed the effect of lower mass of gripper is reflected in power consumption which is lower than that of a shuttle loom. Water jet looms perform best as water, being approximately 1000 times denser than air, applies proportionately higher amount of drag to weft yarn as compared to air stream. This aspect is responsible for superior energy utilization.

In terms of achievable maximum reed width, commercial water jet looms can operate with reed width in the region of 2.5 m while gripper looms and the latest generation air jet looms can weave with about 5.5 m reed width. Monophase rapier looms with reed width of 4m or slightly higher, occupies an intermediate rank. Indeed if WIR is left out of consideration, the gripper technology is eminently suitable for much higher reed width of even up to 12m. Inability of water jet loom to operate with more than one nozzle, sharp rise in energy consumption of air jet loom with increasing number of relay jets and considerations of high energy and space consumption as also problem of buckling of guiding elements of rapier looms limit values of maximum possible reed width. A free flying gripper on the other hand caries enough kinetic energy to cover very high distance if restriction on flight time is done away with.

All shuttleless looms exercise a degree of continuous control on weft thread during its insertion. This control comes from the tensioning and braking systems mounted on yarn feeding module. A perusal of figures 6,11,19,23 and 28 helps to develop an understanding of essential differences in nature of variation in weft tension caused by the different propulsion systems. Air jet and gripper propulsion systems accelerate weft rapidly from rest and hence there is an impactual shock on yarn before it is accelerated to flight velocity. Subsequently this tension is kept steady over the entire flight. In jet looms repeated and programmed braking of yarn during latter part of its flight decelerates weft thread while in griper loom the gripper is gradually brought to a halt by magnetically operated brakes. Such differences in deceleration of the weft create differences in their tension profiles. The tension profile of weft carried by rapier is entirely different from those of jet and gripper looms, as has been illustrated in Fig. 11 and discussed in detail in section 3.2

15 Name the salient features of a modern air jet loom that has contributed to its growing dominance of the shuttleless loom sector. Which features of rapier, projectile and water jet insertion principles do not permit such a development?

Ans A modern air jet loom operates with a high WIR and high reed width and can handle a wide range of weft threads. Supplying clean air at a pressure of 5-6 bars involves relatively simple and inexpensive technology, although it is energy consuming. Sourcing and continuously supplying clean water on the other hand is a complicated matter, limiting widespread use of water jet technology. Moreover water jet looms can process only hydrophobic materials and operate with relatively narrow reeds. The WIR and reed width of rapier looms are limited by inertia of the propulsion system, its displacement function, greater throw of reed, problem of buckling rigidity of rapier band and larger space requirement. The WIR of gripper loom is limited by the inertia of propulsion system as also by a relatively high throw of reed.

16 Considering the equations governing the motion of projectile and that of the weft dragged by air jet explain the difference in the nature of velocity profiles of the corresponding weft threads.

Ans Typical velocity profile of a gripper is provided in Fig. 6. A piece of weft dragged by gripper would follow exactly same velocity profile as that of gripper. The velocity profile of a weft thread dragged by air jet is shown in Fig. 23. There are broad similarities between the two in the sense that in both cases velocity of weft initially picks up from a state of rest to an average value of flight velocity which is broadly maintained till the other end of shed is reached, followed by a sharp deceleration to rest. However during flight within shed a weft thread pulled by gripper exhibits a more uniform profile as opposed to that dragged by air jet stream. This is caused by synchronized switching on and off of numerous relay jets which keep on accelerating the jet stream while the stream itself keeps on dissipating in the surrounding atmosphere while negotiating atmospheric drag. Braking of weft in flight takes place in a modern air jet loom in finite steps while braking of a gripper occurs only after it has safely crossed the entire shed. This aspect also introduces some difference between weft velocity profiles of the two systems.

17 Keeping the overall trend in development of shuttleless looms in view, justify the growing commercial popularity of air jet and rapier looms.

Ans Read answers given to questions 14 and 15 . They underline the reasons for growing commercial popularity of air jet and rapier looms in traditional textile production facilities. However the gripper propulsion system scores over these two in terms of energy consumption, maximum possible reed width and ability to handle with a high degree of reliability a range of high performance fibres such as Glass, Kevlar etc. It may be recalled that only a gripper and a Dewas rapier grip weft by its tip whereby the tip-to-tip transfer in Dewas can prove unreliable with certain kinds of weft thread. Hence for production of technical textiles the gripper system would be preferred if the economics permits the same.