Medium Speed Headbox - its Design and Construction

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INTRODUCTION

The demands made on paper quality in the form of formation are steadily rising. A good formation of the paper web on the wire section of a paper machine calls for even distribution of fibres over the whole width with maximisation of drainage and retention and minimisation of flocculation. A headbox is used to produce a uniform stock jet over the wire width and also as a correcting element to obtain a uniform paper web. The uniformity of the web is distributed by the local fluctuations in velocity of the jet. Therefore a Headbox has to control the intensity of the turbulence in the jet to such an extent that the flocculation tendency of the fibres in the suspension is kept at minimum. With these functions to be performed, the design directives of an ideal medium speed headbox may be summarised as follows:--

1. Optimum design of hydrodynamic flow passages without any secondary flow and no cross currents at the discharge slice.
2. Shortest possible flow path from the distributor to the slice to allow minimum time of flocculation.
3. Small stock volume to create turbulent flow conditions.
4. Application of perforated rolls to stabilise the velocity profile and control of turbulence.

DESIGN AND CONSTRUCTION

A medium speed headbox can run upto a speed of 900 m/min with stock varying from 15 to 200 gsm. These types of headboxes are basically consisting of distribution header as approach system, nozzles inside the headbox, perforated rolls between nozzles, slice lip and apron board as foundation (figure-1).

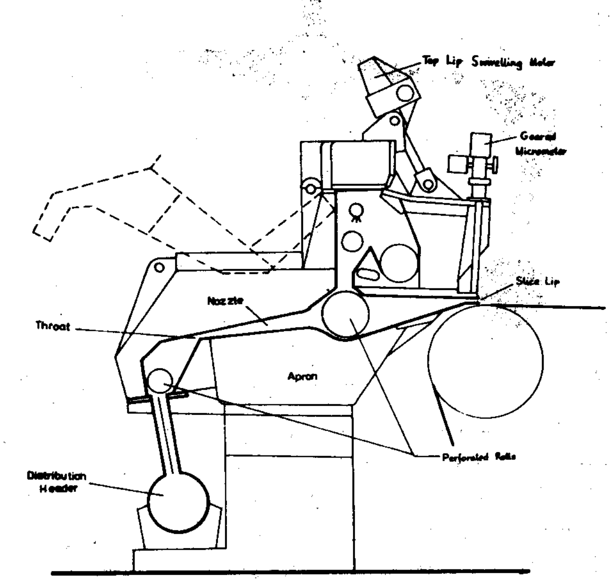

Figure 1

Distribution Header

The distribution header receives stock at about 0.3 to 0.5% consistency from vertical screen and directs the flow of the suspension to the discharge slice. Among different types of approach system, the most popular one is the one-sided inlet with a controlled re-circulation and a gradual tapering from one side of the machine to the other. Discharge into the headbox is effected upwards through large number of short stainless steel tubes. The velocity distribution of stock through the headbox is shown

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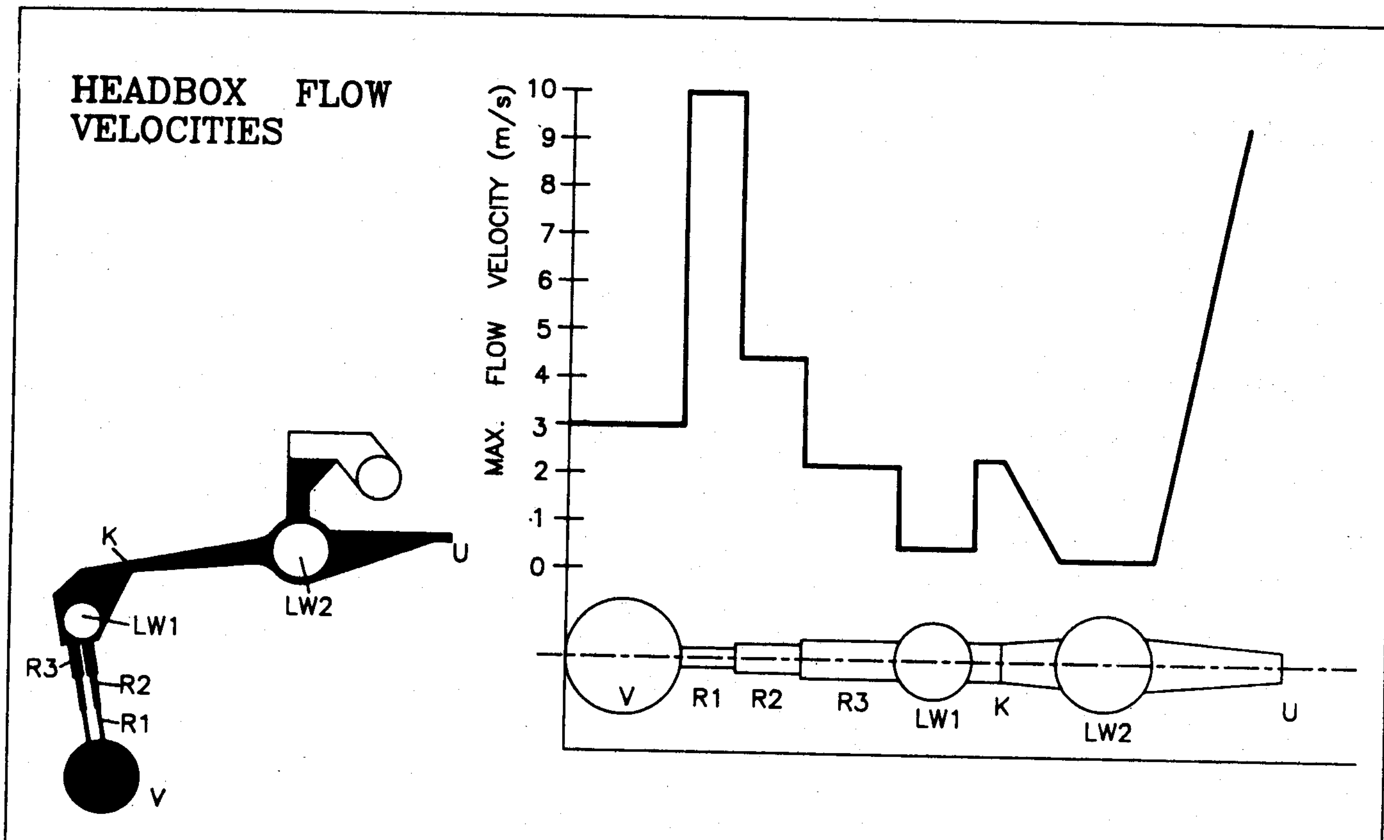

Figure 2

in figure-2 which shows that velocity is maximum at these tubes. Welding of these tubes with the distribution header is not recommended as weld deposits accelerate the growth of flocculation. However the tubes are fitted loosely between two blocks at the manifold and headbox. The diameter of the exit end of these stainless steel tubes is increased gradually by swaging method to reduce the intake velocity of the headbox. Swaging is a cold forming method for reducing the cross section area of bars and tubes using two or more dies which surround the O. D. of the workpiece either completely or partially. These dies rotate around the workpiece and act towards its centre by applying radial forces. The advantages of swaged workpieces are that welding is totally eliminated and by reducing the cross-section of the workpiece, considerable increase in tensile strength and hardness is obtained depending on the workhardening behaviour of the material. In addition, the added compressive stress at the surface of the material increases the reverse bending strength. A swaged cross-section can usually undergo several additional forming operations without heat treatment. A considerable improvement in surface finish is also obtained at increasing reductions of cross-sections. Unlike surfaces produced by cutting, swaged surfaces have a much smoother surface finish and the fibreflow of the swaged part also remain uninterrupted. All these advantages permit to use materials of lesser strength, resulting in lower cost, and at the same time, to increase the strength of the workpiece.

The taper section of the distribution header is parabolic in nature and is designed to give a cross-web profile which remains very stable and fairly independent to the head applied for the flow (figure-3). The overflow through the header is

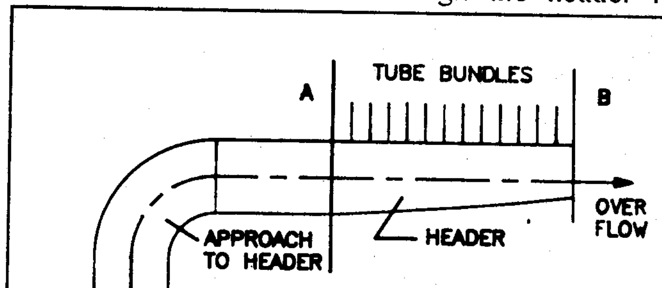

FIG.3

restricted within 10% of the total flow as 10% or more overflow requires a separate pump which means a substantial increase in pumping costs. A large overflow also has the disadvantage of producting fluctuations in consistency of the system. Sometimes a three way cock valve with a flow indicator is provided with the header to ensure zero differential pressure between sections A & B. However in reality, it is not possible to fabricate a header with one side having parabolic profile.

The entire length of the header is divided into 7 to 12 parts each of which is eccentrically tapered in such a way that the actual diameter does not exceed 0.3% of the theoretical diameter (figure-4).

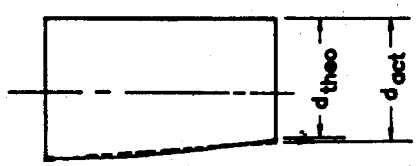

FIG.4

$$\frac{d_{act}-d_{th}}{d_{th}} \times 100 = 0.1 \text{ to } 0.3$$

The length of each short piece, L is a function of larger diameter of the short piece D and empirically may be determined from:

L = 1.175 D (Both L, D are in mm)

Generally the distribution header is fabricated out of 2.5 mm thick stainless steel sheets of low carbon quality and the surface roughness requirement is restricted to 0.85 micro.m.

Nozzle

Uniformity of flow also depends on sufficient head available at the slice lip. This sufficient amount of head is provided by the nozzle portion inside the headbox where a variable pressure is maintained at the top level of the stock. Also the beginning of the nozzle portion takes care of the shortcomings of the approach system to help even out undesirable disturbances and poor uniformity. Initially the nozzle is divergent with angle of divergence is about 6^0 to avoid boundary layer separation of stock which generates eddies to the flow pattern. The throat of the nozzle is designed to restrict the velocity of stock at 2.5m/s as higher velocity has an adverse effect on flow stabilisation. The throat also provides reorientation of fibre in MD due to relatively larger velocity at this location. The length of the divergent channel is designed in such a way that sufficient time (3 sec) is not allowed by the flow for growth of dead spots, settling of fibres and flocculation to occur.

The later portion of the nozzle is convergent and utmost care is taken to ensure uniform cross section of the nozzle throughout the width of the headbox. Any non-uniformity in cross section generates variation in secondary flow which is always perpendicular to the main flow and leads to faulty CD profile. Hence if bending occurs at the nozzle due to pressure and temperature, it must be automatically compensated by a separate anti-deflection control unit. Constructionally it is more economical to fabricate the body of the headbox from mild steel with lining of stainless steel sheet at the stock contact portions. Hence highest degree of workmanship is desired while fabricating the headbox body.

Perforated Rolls

The adverse effects of hydrodynamic stability on paper making are generally compensated by using perforated rolls inside headbox. One perforated roll is placed at the beginning of the nozzle and the other one is placed in front of the converging portion of the nozzle. Both these rolls stabilise the flow disturbances created by headbox passages located just upstream of the rolls. These rolls are very effective tools for medium speed headbox in dispersing the fibres and induces a degree of small-scale turbulence. It also dampens larger eddies during flow stabilisation process. The fibres are dispersed not only in horizontal direction but also in the vertical direction and settling of fibres is avoided. The rolls also reduce any tendency of flocculation due to the high shear forces experienced as the stock is accelerated through perforations. The variables related with perforated rolls are the position relative to the slice, hole diameter, open area and speed and direction of rotation.

Analysis of flow past a cylindrical body shows that boundary layer separates from the body at certain location which generates eddies and is

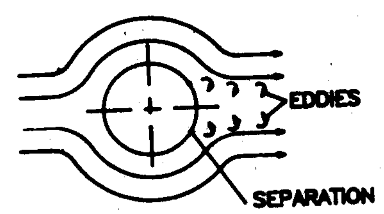

FIG.5

carried away by the downstream flow (figure-5).

This wake of disturbances is not at all desirable at the slice lip and sufficient flow path must be provided between perforated roll and slice lip to dampen the disturbance. Generally the minimum distance is kept about twenty times of the hole diameter. Therefore a compromise has been done in selecting the hole diameter and it is normally kept between 16 to 25 mm. The roll diameter is selected considering velocity in the range of 0.25 m/s to 0.50 m/s at the roll locations. however slower velocity is recommended at the roll nearer to the slice.

Regarding selection of open area & speed of rotation, lot of research work has been carried out in several countries. It is now accepted through experimental research work that the roll away from the slice should have 40% open area while the roll just ahead of the slice should have 48 to 50% open area. However for long fibres the open area is to be reduced to 43% or less to avoid the risk of fibre stapling. A relation between hole dia. and open area can be established as follows:

$$x.p^2 = \frac{\pi}{4}.d^2$$

where, x = open area in percent
p = pitch of hole perforation
d = hole diameter

It is important to rotate the roll to keep it clean, however the magnitude of rotational speed should be such that it is fast enough to avoid stapling of fibres but not so fast to occur hydrodynamic disturbances. It is also recommended to rotate the roll against the flow at the bottom to reduce the possibility of approach system disturbances passing straight to the slice. The peripheral velocity of the roll is kept 10-16 m/min. and it is important to keep the speed constant. This constancy of speed is achieved by using hydraulic motor with gear coupling to drive the perforated rolls. Generally for higher throughput or larger fibre. lower speed is recommended.

The gap between the roll and headbox wall must be even throughout the machine width so that unstable flow condition can be avoided and also to avoid by-pass of stock fibre without meeting shear forces in the holes. This gap is kept in the range of 4-5 mm throughout the machine width. Constructionally a perforated roll must be rigid enough to cut down any deflection. It is manufactured from highly polished austenitic steel of 5-6 mm thick. Some of the rolls may have fins of disks inside to help stabilise the flow. The ends of the rolls are also punched with circular holes to minimise the edge effects due to side walls.

Slice Lip

Once stock is flown through the slice on the wire no furthur correction to the basis weight of the paper across the machine can be done. Therefore slice lip is the last portion of the headbox where any deficiency in flow uniformity can be adjusted. Also the slice opening in relation to the pressure head determines the volume flow. and hence the consistency of the headbox. In a medium speed headbox, a slice blade of projection type is used. Here the slice blade is projected at 60^0 with top lip. The slice edges must be kept absolutely clean and surface roughness quality is acceptable in the range of 0.25 micro.m. The edge of the slice blade is slightly rounded off to avoid collection of any element. However if rounding off is too great, air is liable to disturb the flow of jet by creating air pockets. The bottom lip is extended by about 10 - 20mm from the top lip and care must be taken during construction to ensure that there is no discontinuity across the machine. This extension between the ends of top and bottom lips is maintained to make the direction of jet more horizontal. The more horizontally the jet hits the wire. the less will be disturbance. Approximately the gap is equivalent to twice the slice opening.

The slice blade is adjusted to achieve the desired thickness (t) and the velocity of the jet. It is adjusted by means of several jackscrews placed at equal intervals over the whole width of the machine. These jackscrews are individually connected with geared micrometer at the other end. The micrometers provide adjustment of the slice blade in the range of micrometers through which the CD basis weight is corrected. The interval of the jackscrews are determined from the criteria that there will be no permanent deformation in the blade between the two adjacent jack-screws.

The slice blade is manufactured out of solid stainless steels plates in single piece. Facility must be available with the manufacturer to hold the piece in machine without any bending deflection during machining and grinding. It is absolutely necessary to overcome this deflection problem as it can not be rectified afterwards and if the straightness is not maintained, CD basis weight variation will occur during operation.

The chance of introduction of any bending moment on the slice blade is also eliminated by keeping the slice blade and the jackscrews in the same plane. The jet thickness (t) can be determined by the relation, $t = S.K_f$, where Kf the jet discharge co-efficient and is a logarithmic function of s and r (figure-6). The values of Kf are established experimentally and can be given as follows:-

r (mm)	Kf
2	0.542 + 0.097 ln (S + 1)
3	0.523 + 0.095 ln (S + 1.5)
4	0.529 + 0.087 ln (S + 1.5)
5	0.516 + 0.085 ln (S + 2)

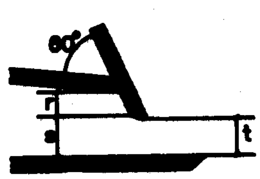

FIG.6

The jet speed depends on the pressure applied on the stock. The pressure may be vacuum or higher than atmospheric pressure depending on the required speed. The pressure chamber is connected with a separate air tank and blower which can be controlled independently. The speed of the jet is kept slightly (±3 – 4%) different from the wire speed. If the jet speed is more than the wire speed, the phenomenon is called as rush and if the jet speed is less, it is called drag. This is done to provide a shear force in the web during drainage at wire section. The shear force provides favourable condition for formation of fibre in MD. However if the variation of the jet speed is kept more than 6% of the wire speed, distortion of paper may occur.

Apron Board

The apron board provides a machine-wide foundation resistant to bending and vibration. This ensures trouble-free operation of headbox. Specially designed soleplates and strong tie rods clamp the very rigid table firmly to the foundation and do not allow thermal deformations due to differences in temperature between stock (apron upper side) and apron base.

The bottom lip beam is pivoted to the apron board as a separate solid stainless steel section to ensure proper bottom lip contact. The bottom most point of the apron is provided with a drainage pipe controlled by a valve which drains out stock during maintenance.

CONCLUSION

The headbox in medium speed range is widely used in Indian Paper Mills. Continuous research and development work is still going on to satisfy the specific requirements of the end users. An elaborate discussion on the major components of this type of headbox is made with a view towards its suitability among end users. Critical aspects during different manufacturing stages are discussed highlighting their effects on the headbox performance. However for selection and specific utility, Indian paper mills may keep constant touch with the

Suppliers or Manufacturers.

REFERENCES

1. Theory and Operation of the Fourdrinier Paper Machine- G.H. Nuttall.

2. Demands made on the Headbox for basis weight CD profile control - H. Kiessling, J.M. Voith.

3. The influence of the Headbox on Asymmetry in Paper - D. Egelhof, J.M. Voith.