Cylinder Paper Machine

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Introduction

Although a large number of different paper making machines have been devised during the past 150 years to accomplish the sheet formation they have all evolved from two basic systems—the Fourdrinier machine and the cylinder machine. The first was invented by a Frenchman, Louis Robert in 1799 and was successfully run with modifications on commercial scale by the Fourdrinier brothers of England, hence named after them as Fourdrinier Paper Machine. Since that time many novel and important changes have been made with respect to speed and size of the machine.

The second system was invented by John Dickinson of England in 1809 and was known as cylinder machine. The cylinder vat together with cylinder mould is the leading characteristic of the machine. In the early days immediately after its invention, the cylinder machine received more attention because of its simple design and easy operation and forced the Fourdrinier into the background until about 1830 when its importance was finally realized. This system has also undergone development and modifications and today multiple vat units equipped with various means inside the forming roll have been combined successfully for the manufacture of multiple boards and papers. And almost 40% of the productive capacity of paper industry is represented by the cylinder machine.

The general principles of paper formation on the cylinder machine are exactly the same as those applying to the Fourdrinier machine; although the two systems differ basically in the method of supporting the forming mesh and methods used to control drainage through the forming medium. The cylinder machine has, however, certain inherent advantages over the Fourdrinier in producing uni-directionally strong and bulky paper and boards. When such a paper needs to be bulky or thick in order to provide 'cushion' to absorb shock or for economy in furnish materials, we look to this porous cylindrical structure fulfilling the conditions with superior performances. On comparing the physical conditions of the sheet formation on the conventional cylinder mould with those on a Fourdrinier wire, it can be reasoned that cylinder mould will produce a sheet much stronger in the direction of flow than that produced on the Fourdrinier.

On the Fourdrinier wire, the flow of stock suspension through the slice and over the apron is allowed for a very short period of time. There is no flow during consolidation of the sheet on the wire. As again this, on the cylinder mould, the stock suspension is moving between the vat circle and mould face during the whole time in which formation takes place. The wire covered cylinder mould is always moving faster than the stock in spite of the efforts to prevent it, so there is a double influence to align the fibres in the direction of travel. For this reason cylinder machines are superior to Fourdriniers in the forming of twisting tissue, chip board and box board, etc., where directional strength is an essential feature.

Structural Details and Operation

In its simplest design, a cylinder machine is that in which the forming wire-mesh is supported by a porous cylindrical structure, through the spider arms extending from the

shaft. It is covered with two wires of different mesh. The inner-wire known as backing wire acts as a supporting base for the top or facing-wire and is usually of 10 to 15 mesh. The top wire is a phospher-bronze wire of 35 to 60 mesh usually plain weave (or twill weave) and for special purposes of 80 mesh. Partially immersed in a stock suspension it rotates in the vat and allows water to drain through the wire cloth leaving fibrous deposition upon its surface which are in much the same condition as the paper on the Fourdrinier wire after it passes the first suction box. This partially formed wet paper when brought under a felt and couch roll by the rotation of the mould, the smoother surface of the felt picks it up with sufficient force to withstand the pull of gravity. Water is removed continuously from the inside of the mould by a circulating pump and provides the difference in water-level required to maintain the flow in the proper direction.

The simplest design described above will not work out well for liners and tissue papers because the friction between the face-wire and water will move the fibres and will let them be replaced in clots and bunches producing uneven sheet of paper. So to obtain a well formed, even sheet of paper a forming channel called Scroll is provided between the vat and the mould, i.e. the cross-section of the channel is large enough where the stock enters and becomes progressively smaller as it passes around the mould. This keeps the water and stock at the speed of the mould-face and in the same direction that the mould-face is travelling. Chime rings and garter strap arrangements are provided to prevent the leakage of stock from the outside of the cylinder mould into the white-water inside through the clearance between the cylinder and vat ends.

A further improvement is the addition of an apron board to prevent stock from coming in contact with the 'face' before it has been accelerated to the speed and direction of mould-face travel.

Another refinement used these days for toilet tissue is a forming board. Its paper setting will reduce, to some extent, the tendency of fibres to become aligned in the machine direction. This way it changes the character of the sheet and improves the strength ratio, MD Vs. CD. Suction inside the forming roll and inverted suction box over the felt are the other notable features of the recent development.

TYPES

The cylinder machines may be classified into two broad headings such as:

(1) Uni-flow or Director flow Vat type; and

(2) Contra flow Vat type.

The Uni-flow Vat type machines are of more recent design than Contra flow or counter-flow Vat type. Its main feature is that the stock flows on to the wire-face in the same direction in which the mould rotates. Stock enters the Vat at 45 degrees through flow distributors or head-boxes and surplus flows out through an overflow at about 40 degrees controlled by an adjustable dam. The total formation area per revolution of the mould is approximately 265 degrees for light weight papers and 245 to 250 degrees for heavy weight boards, i.e., 70% of the mould diameter. Incidentally it can be mentioned here that in case of Fourdrinier machine formation length is 28.5% of the total wire length. The circulating stock is always heavier in consistency than the incoming stock at the vat inlet. In other words, the fibres being deposited on the mould drain more than their proportionate amount of water. The smaller the quantity of circulating stock overflows, the more pronounced is the thickening effect. So to avoid it, a circulating pump in this system is necessary. As compared with counter flow type, a better orientation of fibres is claimed in this type.

Counter-flow Vat is similar in construc-

tion to uni-flow vat. The main difference is that the incoming stock enters against the directional rotation of the cylinder. The new stock entering the vat circle on the up-turning side of the mould where the sheet is already fromed, is robbed of some of its (water and) stock which is a bit heavier in consistency than it is at the inlet. Thus, the entering stock counteracts the thickening effect and no circulating stock overflow is necessary. One of the greatest disadvantages of this type of vat is that there is greater tendency towards dragging of fibres against the wire-face and the formation takes place in the dead pockets. This type of vat tends to produce a much more directional sheet than does the direct-flow vat. *Couch Rolls* fitted with levers and weights (nowadays with air-loaded cylinders) are used to couch off the newly-formed sheet having 7% fibres and 93% water and cause it to adhere to the felt. These rolls are covered with soft, thick rubber (1½" to 2") having plasticity of 200-240 P & J plastometer and their total outside diameter is about 16" to 24". The softness of the couch rolls is very much useful to even out the 'Hills and Valleys' of the irregular sheet. They also permit large lumps of stock and pieces of trash to deflect the rubber instead of deforming the mould as they pass through the nip. They are ground to a uniform diameter and no crowning is needed to compensate for deflection.

Couch doctor, ordinarily a piece of short rubber or used felt strip is installed in front of the couch nip. It is allowed to drag lightly on the pick-up felt with a specific purpose to cause the water squeezed upward through the felt on each side of the mould where water may be collected in the pockets.

Drainage

Compared with a Fourdrinier drainage and control, the machine tender of a cylinder machine has very little control over the quality of the sheet. The stock condition, basic weight and water-level can be changed ; apron board and forming board can be manipulated, but the stationery circle shape and mould diameter fitting only one drainage rate must be used. Movable cylinders and movable circles have been provided these days for better control of quality of paper, but they have not been accepted universally.

The factors affecting the drainage in the cylinder machine are enumerated below : —

1. Sheet Weight.
2. Freeness of Stock.
3. Temperature.
4. Uniformity of formation.
5. Area exposed.
6. Head differential.
7. Wire mesh.

The sheet weight is a specification of the order. On increasing its weight drainage will retard. Freeness of stock is the property of finished paper. Refining a stock will greatly improve the formation, but decrease the drainage rate and may make the paper hard and brittle to correspond to the desired grade. Temperature of stock influences its viscosity and ease of flow. Raising a stock temperature is a means to increase the drainage rate. High temperature, however, leads to foam and slime problems and often to a loss of formation. The head differential which forces water through the mat of stock and mesh of the mould face at a pressure of .036 psi for each inch of level differential is the effective hydraulic force for even formation and higher drainage rate. It is maintained by lowering or raising the level of White Water inside the mould. Higher suction head with low velocity of flow of the mixed volume of stock will produce the more uniform and compact sheet of paper and *vice versa.*

The face-wire is another factor affecting the drainage rate through the cylinder mould. Fine mesh wires result in slower

drainage rate because they catch more of fines and hence build up a dense sheet. Hence it is a common practice on cylinder machines to use a 40 or 50 mesh wire for the filler stock and a 60 mesh wire for the liner stock.

Thus, the optimum drainage conditions are achieved by the pressure applied to the outside and various means utilised within the forming roll (such as suction).

Cylinder Machines—Advantages

1. A single cylinder Vat costs about one-tenth of the price of a Fourdrinier forming part of the same capacity. This was the main factor in the universal use of cylinder Vats for cheap tissues. Lick-up arrangements with the Fourdrinier wire is of recent origin, while it was done from the beginning to felt a sheet off the cylinder faces.
2. Operating cost of the cylinder machine is also much less than that of a Fourdrinier.
3. Cylinder machines can produce one way strength papers.
4. Sheets with different characters of stock can be Vat-plied or formed together to give a wide variety of qualities and colours (White or Coloured Duplex, Triplex Board with fillers as waste-paper are the common examples).
5. For same weight and quality of the fibres a bulkier sheet can be made on the Vat machine than on a Fourdrinier machine.
6. Much less damage is done to cylinder moulds by grit and dirt particles present in the stock.

Defects and Difficulties

1. Strength is always directional.
2. Light sheets are apt to show 'cylinder holes' caused by pitch and dirt sticking to the face-wire and 'slip-holes' caused by centrifugal force at 450 feet per minute.
3. Formation is likely to show thin streaks due to dirty bands around the mould.
4. Single sheet from counter-flow Vats will show large variation in thickness due to wash off and re-attachment from fresh stock.
5. Speed is limited by centrifugal force. If large moulds are used, other formation troubles increase.
6. Multiply sheets generally show 'blowing' in which separation between various plies due to entrapped air is almost invariable. It is aggravated by an increase in the thickness of the board being made. Mainly, the trouble arises due to too wide variation in freeness between liner and filler stock, leaky cylinders, dirty and close felts and uneven couching.
7. Crushing, drop off and cylinder-wrap are the other defects which are uncommon to a Fourdrinier operator. The suction inside the forming roll and use of inverted suction boxes have been proved as a good remedy.

Multi-Vat machines

Multi-Vat cylinder machine is a combination of several Vats each of which has its own independent pump, piping and circulatory system. Fibrous mat formed on each mould is a separate sheet which is laminated while still wet to another sheet at each couch roll by means of an endless pick-up felt which passes over the top of each mould and collects the individual webs into a single composite mat to form a multi-Vat board of desired thickness.

Another combination—Cylinder - cum - Fourdrinier—is in operation which combines a cylinder formed web with that made on a Fourdrinier to produce a sheet having large bulk and mass of a cylinder mould as well as high quality obtained on a Fourdrinier wire.

Until last few years the multi-Vat Cylinder machine was the only means of forming board, but nowadays with the advancement of "Inverformer" together with secondary headboxes it has become possible to make multi-ply boards on the Fourdrinier alone.

A Word About "Formers"

The greatest handicap for the use of cylinder forming parts is the effect of centrifugal force, which limits the surface speed according to the diameter of the mould. The formula for centrifugal force, f is

$$f = mg = mv^2/r$$

Where v = velocity, fps.
r = radius of circle, feet
g = acceleration due to gravity.

To find out at what surface speed, this force will be equal to the force of gravity for 48" diameter mould, solve for

$$v^2 = gr \text{ or } V = 8.03 \text{ ft/sec.}$$
$$= 480 \text{ ft/min.}$$

So at this speed of 480 ft/min. water will begin to rim and at higher speed water will be thrown out from the mould circle carrying stock with it.

This and other operational difficulties led the Engineers and Technologists in the field to develop new forming devices which can be classified under the general headings as "formers". They are similar to conventional cylinder machines in design, but they differ from cylinder machines in that the stock is admitted to the wire-face by means of nozzle or special inlet. In general this forming zone amounts to only a relatively small part or wire circumference. The second general characteristics is that vacuum is applied to the interior of roll to promote drainage by means of a suction box which is compartmented. The 'Rotoformer' is such a forming equipment constructed in several different forms. There are now more than 30 Rotoformers in successful operation in U.S.A. producing saturating, impregnating and corrugating (packaging) paper. It has several advantages: Short pick-up felt used in this system is free from cleaning problem because fibres are not pressed into the felt weave. Lumpy formation is avoided due to the fact that after the sheet is formed it is not drawn through the slurry and formation, once accomplished, is not disturbed. Vaccuum used prevents slip or raining of the sheet.

The Stevens Former which is equally gaining favour had a different type of arrangement. A special pressure head-box equipped with distributor and rectified rolls injects the dilute (15% to 8% consistency) stock on to the cylinder mould through special slice lips. Instead of mould being immersed in the stock, the furnish is fed to an arc at about 20% of the face of the mould. A slight vaccuum (2" to 3" of water) is applied to the interior of the mould. Such design makes possible to run machines even up to 1,000 feet per minute with improved formation. Another arrangement of the Stevens Former uses a separate Fourdrinier-type wire on which the sheet is formed. The wire passes around the mould and from there to a pick-up type couch.

Thus, the development of new forming devices is the result of attempts of Technologists to overcome cost and complexity and to avoid the speed limitations and some of the quality deficiencies of conventional C.M. We are now in an era of rapid change, but we hope that cylinder machines will remain useful throughout this generation as an assembly of Vats.