Ecnomic and Technological Aspects in the Selection of Sheet Forming and Drainage Elements for Paper and Board Machines

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In the design of sheet forming systems, technological aspects are becoming decisive factors today more than ever, in addition to economic efficiency.

Every design principle of a sheet forming system is based on know-how and the latest technology. As a rule, design principles are created for several paper grades. However, today it is also customary to have certain designs for one single paper grade made from quite specific raw materials.

This is the only explanation for the present large number of very modern sheet forming systems which compete with the traditional system-for example, the fourdrinier.

Comparing the most important sheet forming systems, i. e.,

— the fourdrinier
— the fourdrinier with top-mounted top wire
— and the former or twin-wire systems

With one another, we find that paper is produced over different lengths of forming sections.

Sheet formation itself and drainage of the paper web within this aforementioned formation length, however, takes place almost without exception with stationary drainage elements and oxide-ceramic covers.

We see, therefore, that the location and the function of a sheet forming and drainage element are an integral part of the design principle of a sheet forming system.

Between the function and the application of a sheet forming and drainage element there is, however, as we know from practice, a close relationship. For when the function of such an element has been established, the location and the boundary conditions existing at that point determine the selection of the material of the drainage element cover and the associated supporting structure, i.e., the complete unit.

In particular the following applies : the selection of a functional cover and its supporting structure also decides the quality with which a sheet forming and drainage element can fulfill its function at a certain location.

As you can see from our informative literature, Feldmuhle is one of the largest producers of paper and board-and also of oxide-ceramic sheet forming and drainage elements-in Europe.

We develop and test our oxide-ceramic tops together with our papermakers on our own paper and board machines.

Being Feldmuhle, we are therefore very well acquainted with all the requirements which the paper machine manufacturer and the papermaker place on the function of a sheet forming and drainage element.

We know, however, also that the function of a forming board, a foil or a felt suction box may be good, sufficient or unsatisfactory.

To produce good paper it is therefore in any case necessary to have good sheet forming and drainage elements; i.e. rigid, vibration-free box structures with wear-resisting and wire-protecting tops.

To be able to judge the function and economic efficiency of a sheet forming and drainage element it is necessary to know its location within a sheet forming system.

Please permit me, therefore, to go into the most important sheet forming systems and to discuss those

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systems in greater detail which use oxide-ceramic covers and with which appropriate practical experience has been gained.

Fourdrinier

Today, this is still the most common sheet forming system, and is known to us all.

In this system, the paper web is formed on a horizontal wire.

To keep the wire length as short as possible intensive but controlled drainage is aimed at.

The items used for sheet formation and drainage are: forming board, foils (multifoils, vacu-foils, single foils), wet suction boxes, flat suction boxes (drilled and slotted suction elements).

The stock is fed to the wire through the so-called headbox. in the formation section which follows, the sheet is formed into a fibre mat, and drained so, that the fibres and fillers can no longer move freely in the suspension, i.e, sheet formation is completed to such an extent that it can no longer be influenced by the flat suction boxes.

As we can see, the headbox creates the basis of the sheet forming process, and all the elements which are arranged in the so-called formation length influence sheet formation and, above all, the quality of the paper.

As the headbox, particularly on the Fourdrinier, assumes a very fundamental significance, I should like to go briefly into the two most customary design principles for headboxes.

In the rectifier-roll headbox, the stock suspension is distributed through a rectifier roll to a large number of small tubes into a machine-wide chamber, in which high turbulence is created. Due to discharge through a gap and the arrangement of several rectifier rolls, the magnitude of the vortex of the existing turbulence is reduced more and more, as a flow of fine turbulance it then passes through the slice onto the PM wire.

The design principle common today-the high-turbulence headbox-dispenses with rectifier rolls and other rotating mixing elements. It is designed strictly according to the hydraulic laws of turbulence generation.

Turbulence can be thought of as being a vortex flow in which innumerable vortex dimensions of different sizes occur, viewed in time and space, in a vortex order, i.e, statistically distributed.

Each fluid element displays, in addition to its locamotive velocity, velocity fluctuations in all axial directions. The forces created destroy the network of fibres and prevent flocculation.

The cause of the turbulence is the difference in the velocity of flowing fluid particles, particularly in the vicinity of the wall.

The flow close to the wall. also called the boundary layer, influences turbulence. The energy of this turbulence is measurable according to magnitude and distribution.

The aim is to obtain a turbulence energy whose spectral distribution is of such a nature, that with small wave lengths, in the size of the fibre dimensions, there is a high energy portion, and large wave lengths, which lead to troublesome fluctuations in basis weight. are avoided.

High turbulence with a small wave length is known as micro-turbulence.

The high-turbulence hadbox is state of-the-art today. Every machine manufacturer, however, has his own design principle to generate a headbox slice jet with microturbulence.

In summary we can state that :

The headbox creates the basis of sheet formation.

A rectifier-roll headbox generates, particularly at high flow velocities, an unstable jet with longitudinal streaks. whereas the high-turbulence headbox produces a compact jet with short-wave turbulence of uniform intensity across the width.

The function of stationary sheet forming and drainage elements. such as the forming board, foils and wet suction boxes in the so-called formation zone, is therefore to maintain or even improve the quality of the jet stock offered by the headbox. But certainly not to worsen it.

In other words :

In the rectifier-roll headbox the unstable stock jet is to receive additional turbulence energy, and in the highturbulence headbox the stable stock jet should be retained as long as possible and not be negatively influenced.

We therefore find that the inital conditions for sheet formation may have considerable differences in quality. These differences must, however, be taken into account in the selection of the sheet forming and drainage elements.

There are hardly any general rules for the selection of the elements and their covers. Practical experience must be gained and the influence of each individual element on sheet formation and drainag optimized.

Each sheet forming and drainage element, however, has a very fundamental function.

I should therefore like to go into the most important of them :

FORMING BOARD

The principle function of the forming board is to receive the jet of stock emerging from the headbox and to support the wire. The forming board cover generally consists of a wide leading blade and several narrow trailing blades.

The stock jet impinges on the wire in the region of the leading blade. Depending on the paper grade and basis weight. the point of impingement may be ahead of, on or after the leading edge. The leading blade of the forming board must therefore absorb very large forces.

A further function of the forming board is to initiate sheet formation and drainage in a controlled manner. Blade width, number of blades and particularly the open area determine its drainage-promoting or drainage–retarding function and its influence on sheet formation, particularly on the turbulence of the stock jet.

A forming board can fulfill its function only if its cover is made of wear-resisting material. The surface of the cover must be flat, and the scraping edges must be and remain straight.

Cover wear always involves an alteration in the geometry of the blade of cover. The consequences are uneven surfaces and crooked scraping edges as well as non-uniform drainage and disturbances during sheet formation.

This fundamental knowledge, incidentally, also applies to all stationary sheet forming and drainage elements.

A functional forming board also requires a stable box structure.

Box deformations and vibrations during operation are not permissible.

FOILS :

Nowadys foils are the most important sheet forming and drainage elements.

The foil is a dynamic drainage element, i.e., the vacuum necessary for drainage is generated by the foil angle. The so-called scraping edge scrapes the white water off the underside of the wire, which is drawn out of the fibre mat by the preceding foil.

This means : the greater the foil angle and the sharper the scraping edge, the more water is scraped off.

The most important technological aspects for the selection of foils in a given drainage section are :

—the total quantity of the white water to be drained
—the total number of foil blades, and
—the size of the foil angle.

The decision as to how many foil blades are arranged on a box, and how wide the foil blades are, is determined mainly by economic aspects.

The most customary foils today are

SINGLE FOILS

As the name says, this is one single foil blade, which is mounted on a supporting element.

The width of the foil blade in 80-120mm. The foil angle is adjusted by turning the box.

The indisputable technological advantage of the single foil is that the foil angle can be adjusted steplessly during operation within a range of 0°-5°. Adjustment of the foil angle is very simple and fast, Single foils therefore permit optimum adaptation and control of drainage and aheet formation.

If several foil blades are arranged on one box, we then speak of multi-foils.

The individual blades are between 40 and 80mm wide and have a partially ground foil angle, i.e., the foil angle is preset and cannot be altered during operation.

If vacuum is applied to a multi-foil box, we then speak of vacu-foils.

A static vacuum is therefore added to the dynamic foil principle. In practice, this vacuum is hardly larger than 1m water column, and ean also be increased or reduccd easily. Vacu-foils therefore also permit adaptation to and control of the drainage and sheet forming process.

WET SUCTION BOX

The wet suction box is a static drainage element. It works effectively only when a vacuum is applied from an external source.

In practice, maximum vacuums of 1.5 to 2m WG are usual.

A modern wet suction box cover consists of many narrow strips with full-length slots. The strips may be very narrow and the open area of the cover very large (in this case 75%). The wet suction box is primarily a drainage element. Compared to the vacu-foil it has a higher drainage capacity, as substantially more scraping edges are used over the same drainage length.

FLAT SUCTION BOXES

In the case of flat suction boxes a differentiation is made between two fundamental designs :

- Flat suction boxes with holes
- Flat suction boxes with slots

With both covers, uniform drainage across the width of the web is possible only if the percentage of open area is equal to the percentage of the closed, i e., wire- contacting area. This requirement must be fulfilled in the direction of wire travel at every point across the width of the cover.

The cover with holes cannot meet this requirement, Owing to the standardized hole design, there is an open area tolerance of approx. 6%. This means that drainage across the width may fluctuate by up to 6%, i.e., it is not uniforn. The consequence may be streaks in the paper, especially when the vacuums are greater than 1,5 m W.G.

Similar conditions also apply to the so-called "herringbone" cover.

Covers with longitudinal slots, however, meet the afore-mentioned requirement fully. They drain uniformly across the width. Streaking is ruled out. For this reason, they are used today in the first suction box positions before the drying line.

The most important economic aspects in the selection of flat suction boxes are wire wear and drive power. Both factors are determined primarily by the wire-contacting surface of all elements which touch or support the wire.

From literature and practical operation we know that wire wear and drive power may be caused up to 60% by the flat suction boxes.

The main portion of the frictional force, which counteracts the wire tension, is therefore determined by the flat suction boxes.

The frictional force is a function of the friction coefficient between wire and box cover and the sum of all normal forces, i.e., the sum of all vacuums.

The frictional force, i. e., the drive power, is therefore determined especially by the material of the box top.

On the basis of practical experiences gained we can proceed from the following coefficients of friction :

Synthetic cover—synthetic wire	0.3—0.4
Ceramic cover—synthetic wire	0.05—0 07

From this comparison it becomes clear that a considerable reduction in the drive power is possible with ceramic covers.

To minimize wire wear and drive power, the holes in holetype suction boxes are slightly rounded in the hole inlet. On slotted suction boxes the edges of the strips are slightly rounded.

The important thing with flat suction boxes is also the thickness of the cover. Vacuum losses occur in every hole and slot. The losses are all the greater the thicker the cover.

Ceramic covers are basically much thinner than plastic covers. This means that with the same suction box vacuum there are fewer losses, i. e., the thinner cover has a greater effective vacuum.

An additional increase is possible if the holes and slots are countersunk from the underside of the cover.

In practice this means, that the thinner ceramic flat suction box requires a lower vacuum to attain the same drainage capacity as the thicker plastic cover. Or conversely, the ceramic cover, with the same vacuum, produces a higher drainage capacity than the plastic cover.

DANDY ROLL SUCTION BOXES

Instead of so-called level rolls, a so-called dandy roll suction box can be used under the dandy roll.

2 suction strips and a supporting strip divide the dandy roll suction box into a prechamber and a main chamber.

In the pre-chamber the web is purposely moisturized and again scraped off in the suction chamber subjected to a vacuum of 0.2—1 m WG.

The purpose of the dandy roll suction box is to improve the look-through of the paper and the distribution of the filler, and to avoid picking.

UHLE BOX

The purpose of the Uhle boxes is to dewater felts, to clean felts and to condition them in modern press arrangements. Modern Uhle boxes have, as their primary task, to clean the paper side of the felts and to keep them open. Deposits clinging to the surface of the felt, such as fillers or organic comtaminants like resin, starch, etc. must be drawn off under vacuum by the Uhle box. The Uhle box must therefore ensure the water absorbency of the felt.

Modern Uhle boxes have 1 or 2 slots, according to their location. The slot widths are between 12—16 mm. the vacuums range between 5–7 m WG and the air flow rates may be higher than 100 $1/cm^2$ suction area per min.

At the aforementioned values, which are of course average values, Uhle boxes are subject to high stresses. There are high specific pressures per unit area between felt and cover.

In 3rd and 4th presses in which dry felts are necessary for over-dry increase, so much frictional heat per unit of time may be created that brief temperatures of 180-200° are reached.

These high temperatures may cause the felt fibres to melt and endanger the covers.

In addition to A1203, special ceramics are being used for Uhle boxes today.

They dissipate large quantities of heat fast, and with their high wear resistance and smooth surface create a prerequisite for modern felt cleaning.

We find the sheet forming and drainage elements described using the fourdrinier as an example, partly with a different function, also in other sheet forming systems.

COMBINATION OF SEVERAL FOURDRINIERS

The combination of a fourdrInier with one or more cover–mounted secondary fourdriniers is used above all for thin 2 to 4-ply boards.

Technologically and economically the same applies to the sheet forming and drainage elements arranged in the individual fourdriniers as to the conventional fourdrinier.

The combination of several fourdriniers has brought about the utilization of the good experience gained from two-sided drainage also for single–ply papers.

Thus, in addition to the well known traditional twinwire systems or twin-wire formers, formers have also been developed which can be esily mounted on top of a fourdrinier.

In all twin-wire systems we find, with few exceptions, special sheet forming and drainage elements, which have specific functions aud in part, are exposed to very high stresses.

FOURDRINIERS WITH COVER-MOUNTED SECONDARY WIRE

Taking as an example the Beloit Bel Bond, we see that, as first of all with a conventional fonrdrinier drainage takes place drwnwards and then a large part of the remaining white water is removed upwards through the 2nd wire.

In the formation length, where both wires touch, we find exlusively elements which have a curved surface.

The first element, the so-called "lead in" is found as a solid ceramic cover or as slotted cover Its function is to form the sheet and, if necessary, to drain it in a controlled manner.

Then the free white water is pressed through the second wire upwards into the likewise curved inverted vacuum box and drawn off there by suction. The CIVB has logitudinal slots. The wire-supporting blades are curved according to wire travel and can be pulled out.

The successive transfer suction box again has longitudinal slots. In this case, too, the wire-supporting blades are matched to the wire travel, i. e , they are partly curved ard partly flat. In this case, too, the blades can be pulled out.

The transfer ensures that the paper web remains on the bottom wire when the two wires separate again.

In the well-known Symformer designs, too, we find special sheet forming and drainage elements with a special function.

The so-called vacuum blade shoe with curved surface has the function of draining the sheet through both wires, of improving formation, of reducing porosity, of influencing the distribution of fines and of improving opacity. The special function of the shoe bars is to scrape off the water and to support both wires. Their surface is therefore curved in accordance with wire travel.

A special function, however, also means, as we can see if we take the Symformer and the Bel Bond as examples, exceptional stress. This may even be extreme if the paper machine is operated at high speeds and synhthetic wires are being used.

For example, curved drainage elements may become "heat sources" in twin-wire formers. The cause is the high normal forces which act on the covers or blades, as the wire tension of both wires adds up. The consequence is high frictional losses, which may lead to thermal shock damage to the cover blades if operating conditions similar to dry running occur.

For special functions and locations ceramic covers with special properties, such as thermal shock resistance and high conductivity, are necessary.

Better ceramic, however, generally means more expensive ceramic.

Now we have arrived at the economic aspect, or the costs.

If the wet end of a sheet former is considered from the point of view of cost, then wearing mechanism, in which the factors cover, wire and filler are involved, plays an important role.

Well, we know from practice that a synthetic wire does not wear out because it is particularly soft or a filler is particularly abrasive, or because it is particularly hard or sharp-cornered. This would be too simple. There are a large number of other characteristics of the wear component concerned, as of the wear system, which govern the wearing mechanism.

I would like to limit myself to the most important components which are.

wire—cover—filler—water

First of all, we are dealing with two solid bodies, i e., wire and cover, which move against each other at a certain relative speed.

Between the bodies there is the stock suspension as an intermediate layer.

Initially we are interested in the frictional condition in which the system is found under operating conditions, i.e., is there.

— dry friction
— mixed friction
— or fluid friction ?

As the so-called intermediate layer, i.e., stock suspension, is steadily drained, we are dealing mainly with mixed friction.

Mixed friction is characterized in that the transmission of force between the frictional components takes place partially by direct contact of the solid bodies and partially by the film of lubricant between the surfaces.

Added to this erosive wear, which is caused by solids, i.e., the fillers.

Further factors which influence our system are the vacuum of the flat suction boxes and the speed of the wire. That the rate of wear increases when these parameters rise is well known.

The entire consideration is therefore now concentrated on what happens between the surface of our pair of wearing components.

IN OTHER WORDS :

What effects has the ceramic cover on its surroundings and what are the wearlng conditions like with regard to the wire and the filler.

Let us first consiner the filler :

The decisive factor for the erosion or abrasion wear of the sliding components, especially of the wire, is what filler in what concentration is in the intermediete layer.

The higher the filler content, the shorter the wire life-time—we know this interrelaionship from practice.

A strong influence of the wear behaviour, however lies in the filler with regard to its chemical and mineralogical composition and the associated properties, such as hardnass, particle shape and static charging effects.

Within one and the same filler the particle size of the individual particls or of the agglomerate, or more precisely, the size distribution of these particles, plays a decisive role.

Furthermore, the quantity of hard substances, such as quartz or feldspat, in tne filler strongly affects the wear behaviour.

Particle size or grain form of the individual substances may then be very different.

For example, the hard quartz may stick in the coarse fraction of the filler, and its grain shape may be different from that of the kaolin.

Laboratory tests, and also practical experience, clearly show that wear is determined more by the particle size and less by the quantity of a certain substance.

While the wire can hardly influence wear, that is, it is largely constant, the surface property of the cover material plays an important role.

For the dwell time, especially of the abrasive coarse particles of the filler in the intermediate layer, the size and distribution of the surface porosity is of significance.

Particularly large pores in the cover surface are detrimental to wire wear.

Hardness, strength and abrasion resistance in high-quality ceramic are variable only under certain conditions, and like corrosion, play a secondary role in wear.

There are certain possibilites of influencing wear by chemical additives in the stock, such as retention agents.

Ways of influencing wear are also offered by so-called dispersers, with which the electrostatic charging of the single particles can be influenced.