Papermaking

PAPERMACHINE – PRESSING

1. INTRODUCTION

The paper web formed on the wire part or the forming section passes onto the press section. Pressing of the web on the paper machine follows entering of wet web through the nip of two rolls running under pressure. Under the effect of pressure between the two rolls further water removal of paper is obtained and its compactness and strength is increased. The pressing operation is important for the capacity and economy of a paper machine and has great influence on paper quality. It determines the dryness of the sheet entering the dryer section. It has a major impact on the structure and runnability of the paper and thus the operating efficiency of the machine (Wahlstrom, 1969). The dewatering capacity of a press section and the properties of paper depend on the design and the number of nips. The risk of web breaks is determined by the general design of press section and the arrangement of open draws if any. A modern press section should fulfill the following requirements:

- The highest possible dryness to be obtained with least number of nips.
- Pressing must not impair paper quality.
- The press section should be a compact, simple and rigid structure.
- Quick felt, fabric and roll changes must be possible.

High dryness after the press is required to reduce steam consumption. Removal of water in the dryer section through evaporation is 7-10 times costlier than on presses and 60-70 times costlier than the wire part, though this depends to a great deal on power and steam costs and the efficiency of heat utilization. Dryness of web in the press part varies generally in the range of 15-21% to 35-55% depending on the grade being manufactured and the efficiency of the wet end operation. By using a high pressure and longer nip time it is theoretically possible to get a dryness of web up to 65%. This is the limit of dryness on the presses because 35% water is necessary for wetting of fibres. It is not possible to remove this water by pressing without damaging the structure of the fibres. Practical limit of dryness on the press section is 35-55% for different papers (Kocurek, Smook).

Pressing has two major objectives. The first is to remove water from the web, up to a consistency of 40-45%. The second is to consolidate the web, to bring fibres into close contact for bonding.

A simple single press nip is shown schematically in below. The web is squeezed between a solid roll and a felt supported by a perforated roll. The water is expelled into the felt and then into the holes of the perforated roll. The latter may be a suction roll. Suction is applied over the pressing zone, and when the roll rotates past this suction zone, the water is released to fly out into trays. Grooved or blind-drilled rolls may also fill this same purpose, as shown below.

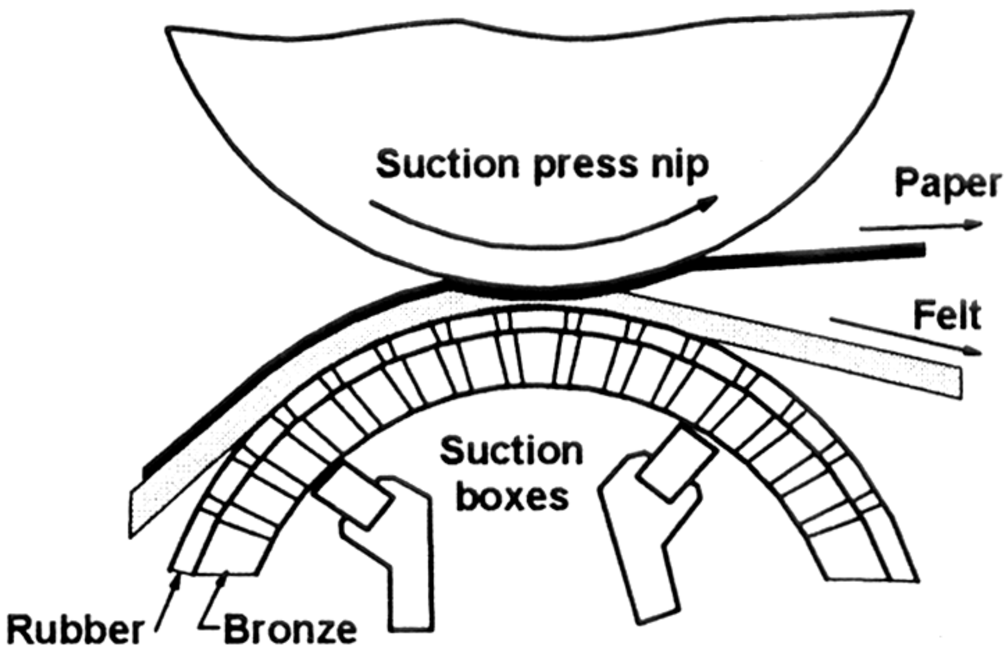


Figure 1

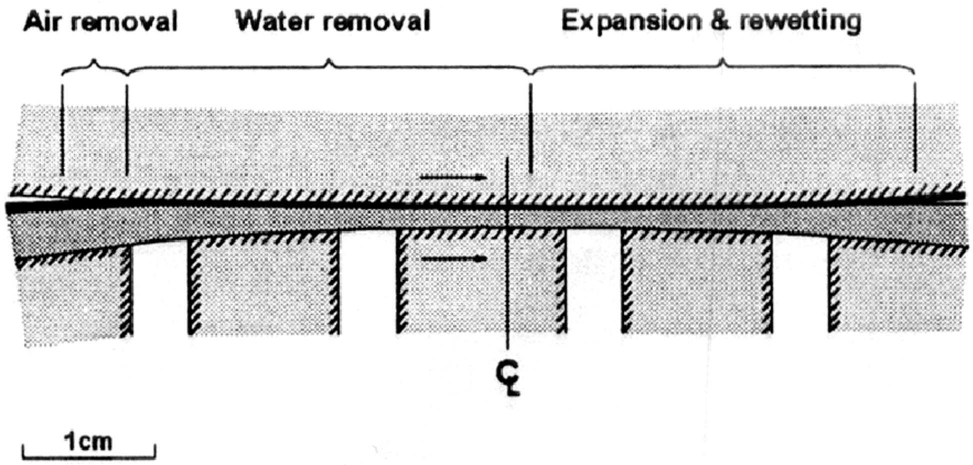


Figure: Scale drawing of the press nip.

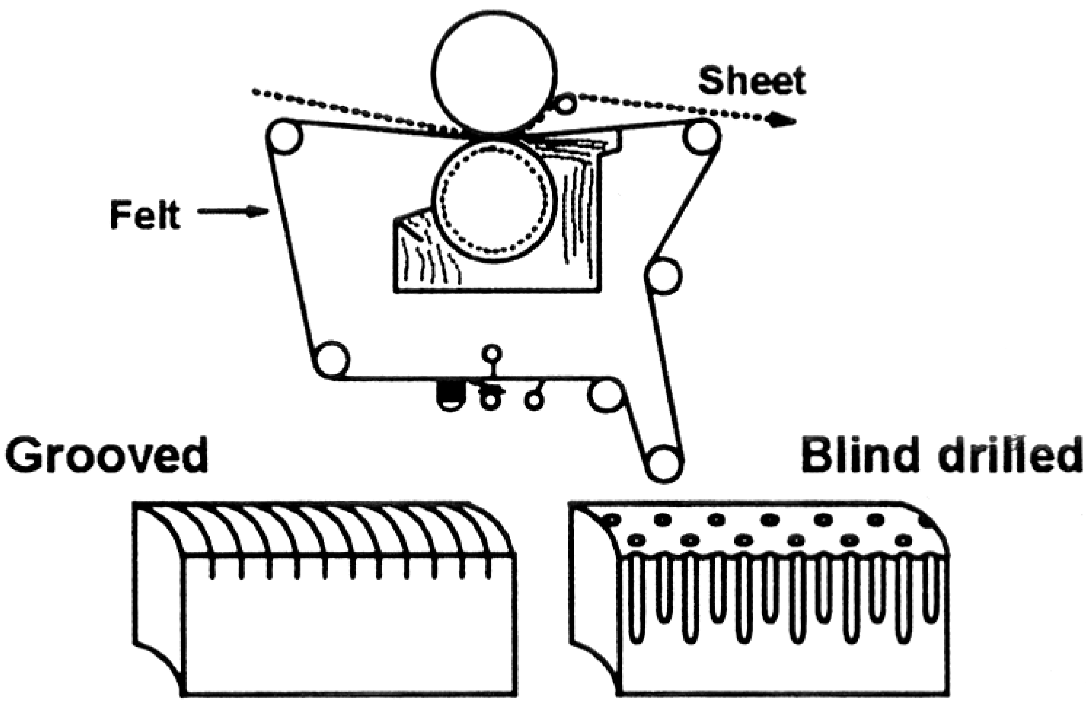


Figure: Felt and the roll surfaces.

2. Theory

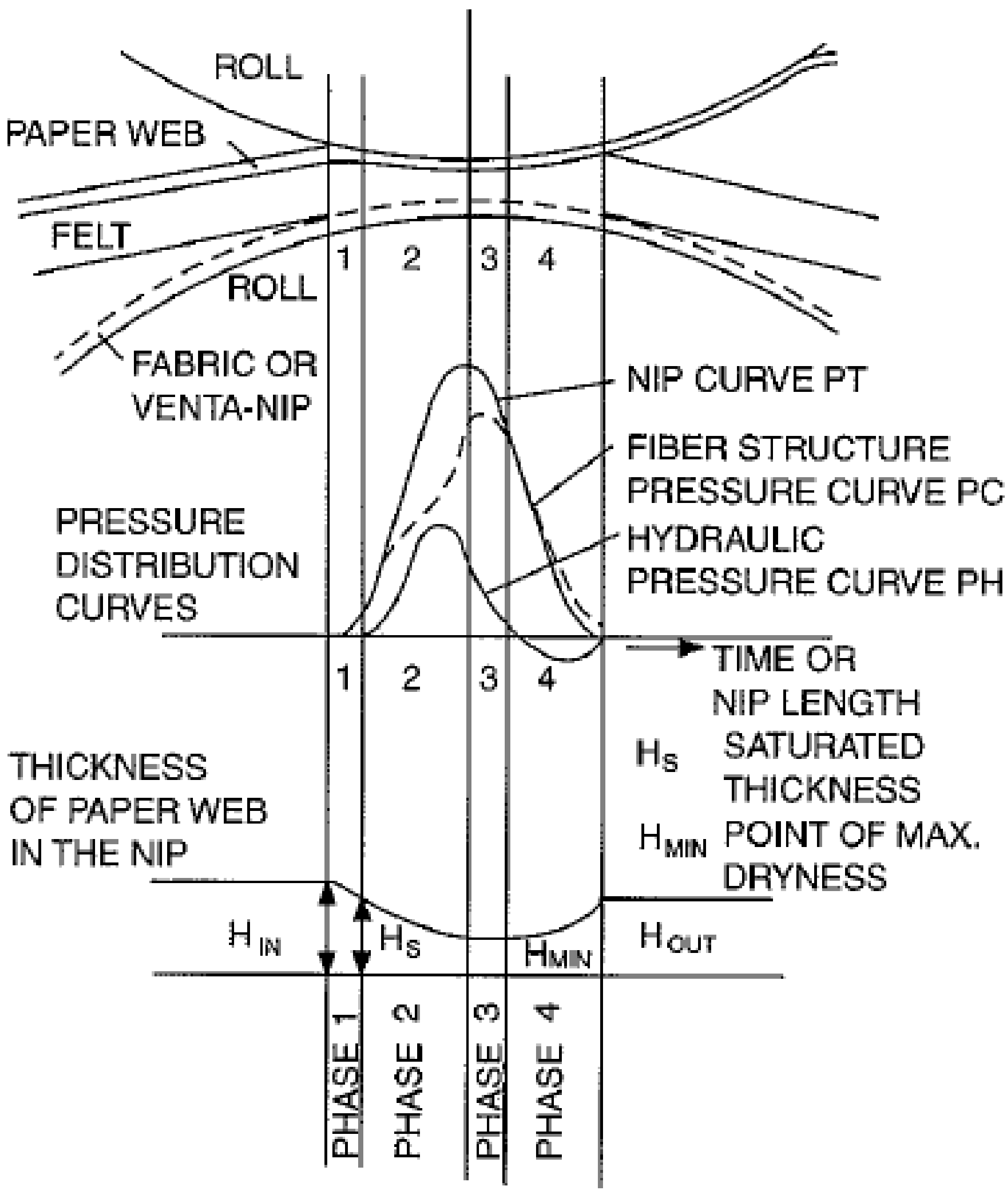


Figure: Nip phases of wet pressing (Pandey, 1983).

The above represents the transversal flow press-nip defined by two solid rolls with paper and felt passing the nip. Both contain sufficient amount of water to reach saturation before the mid-nip. The geometric configuration, pressure distribution curves, water transfer mechanism and thickness curves for paper and felt are shown for the nip. The nip has been divided into four phases,

Phase-1. starts at the entrance of the nip where the pressure curve begins and lasts until the paper has become saturated. The felt is shown unsaturated in phase 1.

Phase-2. extends from the point of saturation to the mid-nip or more accurately to the maximum point of the total nip pressure curve. In this phase felt also reaches saturation.

Phase-3. extends from the maximum point of the nip curve to the point of maximum paper dryness. This point corresponds to the maximum of the paper structure, pressure curve and zero hydraulic pressure in the paper. In this expanding part of the nip the felt passes zero hydraulic pressure and becomes unsaturated.

Phase-4 covers the point where the paper starts to expand and becomes unsaturated. The felt is unsaturated through this whole phase and expands continuously. The total nip pressure curve is divided into a fluid pressure component and a fibre structure pressure component. The sum of these two components is equal to the total pressure. As the felt has much lower flow resistance than paper the fluid component is much lower in the felt than in paper. The fluid pressure component in the felt is dependant on incoming felt moisture and the amount of water being transferred from the paper to the felt.

The proportion of the hydraulic pressure and the pressure in the structure will vary along the nip and through the thickness of the felt and the paper. Hydraulic pressure in the area of paper facing the felt is almost identical to the total hydraulic pressure in the felt. Hydraulic pressure will then grow with the distance from the felt surface and be the highest at the roll. This means that the forces compressing the fibre structure will be largest close to the felt. Pressure gradients therefore, exist both in machine as well as perpendicular direction to the sheet and felt.

In addition to the pressure curve, area is indicated in the figure above to show the type of mechanism acting in different parts of the nip. This includes the flow of water through compression, two phase flow through capillary forces and the two phase flow through compression and expansion .

Phase-1. The total pressure of the sheet increases through compression. In this phase air is expelled out of both paper and felt and there is no hydraulic pressure at this point. Felt and paper are both unsaturated and transfer of water can only occur through capillary forces or two phase flow. Very little change in the dryness of the paper in this phase and all the forces are taken by the compression of fibre structure.

Phase-2. Hydraulic pressure increases squeezing water from paper to felt. In this phase paper and felt are saturated. Hydraulic pressure is generated resulting in the flow of water from the felt into the receptacles under the felt. Compression force acting on the fibre and the felt structure increases through the whole of phase 2. Fluid pressure in the felt and paper reaches maximum ahead of mid-nip. In phase 2 water is flowing out of the system through compression. Before the felt is saturated, there are capillary forces promoting water transfer from paper to felt.

Phase-3. The total pressure curve decreases. The fibre structure pressure increases to a maximum point which is also the point of maximum paper dryness, corresponding to the point where fluid pressure in the paper is zero. This means that paper is getting dryer after the mid-nip as long as there is a hydraulic pressure gradient between the paper and felt. As the phase 3 is expanding portion of the nip and paper in this phase gets still further compressed, the felt must take up all compression. Owing to some lateral flow of water through the nip the felt is saturated through a small part of phase 3 corresponding approximately to the felt forcing air and water to enter from underneath through the fabric or grooves.

Phase-4 Both paper and felt are exposed in this phase and the paper becomes unsaturated. A negative pressure is created in both the structures. Compressive forces on the fibre structure and felt are larger than total pressure. In this phase it must be assumed that air will enter for the same reason as air would enter the felt in phase 3. However, the vacuum due to the expansion will be larger in the paper than in the felt creating a two phase of air and water into the felt and from felt to paper. In addition capillary forces will act within and between paper and the felt into this phase system. When paper and felt are separated at the end of phase 4 water existing at the interface between them will be divided due to splitting. Paper absorbs water from felt. The transfer mechanism is due to the pressure difference between air and water due to expansion.

Press Impulse

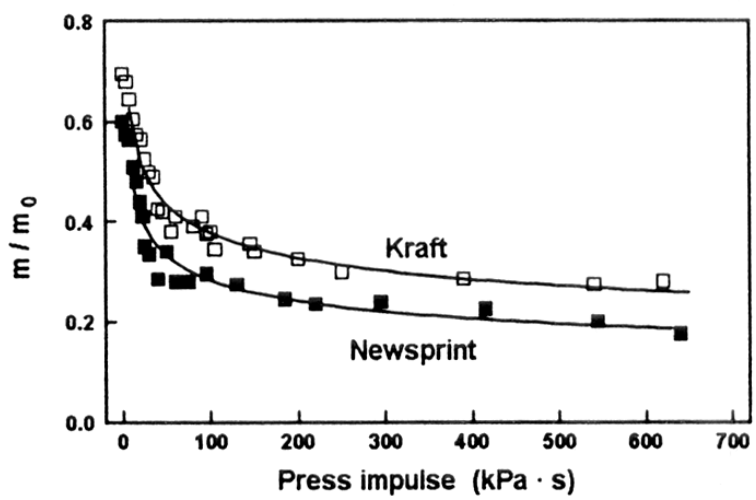
The problem of pressing is essentially one of squeezing water from a compressible permeable medium. The drainage rate is governed by the pressure driving force divided by flow resistance. The amount of drainage is governed by the drainage rate multiplied by time.

The product of pressure multiplied by time is a useful parameter to describe the combined effect of these two factors. This product is called “press impulse”. The press impulse can be determined from the quotient of two readily known variables in pressing, the line loading (N/m) divided by speed (m/s).

$$I = \text{pressure} \times \text{time}$$

$$I = \int_{-\infty}^{+\infty} p(x)dt = \int_{-\infty}^{+\infty} p(x)\frac{dx}{V} = \frac{P}{V}$$

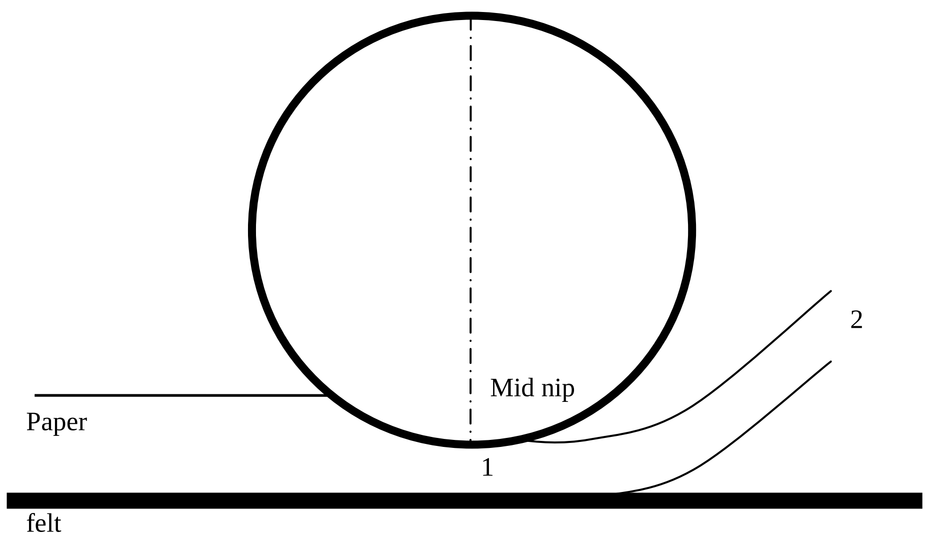
p(x)	**pressure at x in nip (N/m^2)**
t	**time (s)**
V	**speed (m/s)**
P	**line loading (N/m)**



Rewet

As the nip expands after its mid-point, the pressure on the web diminishes, perhaps even giving slight suction. At the end of the nip, there is a “film splitting”, with some water staying with the paper web and some with the felt. Thus, the water content leaving the press nip probably greater than greater than that within the nip. The higher moisture exiting the nip has been called ‘rewet”.

We can estimate the amount of rewet by conducting a mass balance:



$$\left(M_w\right)_2 = M_R + \left(M_w\right)_1$$

Divide by mass of fibres (W=Basis weight, A = Area)

$$\frac{\left(M_w\right)_2}{WA} = \frac{M_R}{WA} + \frac{\left(M_w\right)_1}{WA}$$

Of we can say that

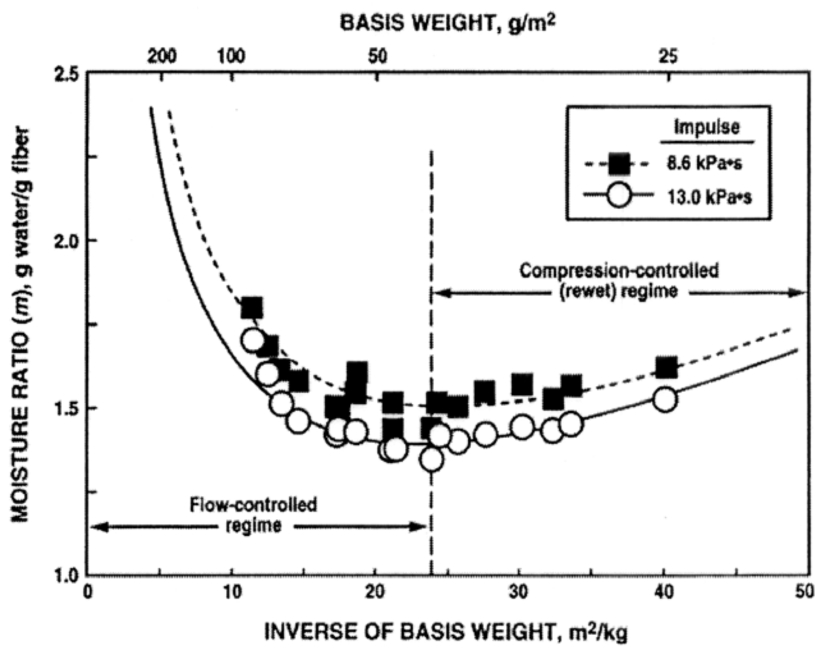
$$k_2 = k_1 + \frac{R}{W}$$

Were K_1 and K_2 are the moisture ratios of (grams of water / grams of fibres) at points 1 and 2 respectively.

Note that the moisture is related to consistency by

$$k = \frac{1}{C} - 1$$

Thus if we know the consistency of the paper leaving the press and the basis weight of the paper we can calculate the rewet, R. In practice you could do this by plotting k_2 versus 1/W and find the slope at high consistency which is R.



This is called a "Sweet plot" as shown above from webs of differing basis weights pressed under the same condition. The resultant moisture ratio is plotted against the inverse of basis weight. The straight line portion of the curve is extrapolated to zero. The intercept reflects the condition of zero rewet.

FACTORS AFFECTING WATER REMOVAL AT THE PRESSES

The basic concepts of pressing first formulated in the late fifties by Wahlstrom and a great many others. Pressing is basically a flow phenomena controlled by flow of water between fibres and from the fibre wall. The structural resistance from the fibres themselves is normally a minor portion at today's dryness levels of between 30% and 50%. The distinction between pressure controlled and flow controlled pressing is very important in understanding pressing (Wahlstrom, 1976). In **pressure controlled** pressing the resistance to flow between fibres is insignificant. The dryness is then basically determined by the resistance to flow out of the fibre wall. The driving force is the press impulse with an independent positive contribution by the specific pressure. Hydraulic pressure for low basis weight sheets the hydraulic pressure at the solid interface is only a small part of the total pressure. By increasing the basis weight we reach **flow controlled** conditions. At these conditions, further increasing the basis weight does not increase the water removed, which stays constant for a given set of press conditions. Under these conditions, the hydraulic pressure at the impermeable surface is equal to the total pressure.

The minimum time concept is even more important. The minimum time defines a minimum nip width characteristic for a given press operation. As the time available for compression is equal to the nip width through machine speed, minimum time becomes critical at higher speeds. Pressure and time data for different kinds of papers will be of extreme importance for optimizing press performance especially for flow controlled pressing at high speeds. It's difficult to maintain pressing time at higher speeds, hence the need for larger rolls, wider nips and more compressible felts are the latest trends in pressing (Wheeler, 1991).

Nip width has been shown to be an important factor in pressing for two reasons. At a given pressure nip width determines the average specific pressure and to a degree the pressure distribution curve. Nip width is therefore an important factor in defining the driving force in a specific nip. The nip width is defined by the total compression of the felt, paper and rubber in the nip and the size of the rolls, disregarding the flow of rubber in the nip.

The variables affecting water removal at the presses are as follows:-

(a) Nip pressure: Water removal increases exponentially with increased nip pressure. Increasing nip pressure is one of the most common and best methods of increasing water removal. Pressure on the presses is applied in ascending order and then only it is possible to give high pressure on the last press without crushing the sheet. Number of presses depends on the degree of refining of stock, machine speed and amount of water removal (Pandey, 1983).

(b) Speed: With the rise of machine speed drainage time is reduced which reduces drainage. Pressing time is inversely proportional to the machine speed. It is necessary to increasing the pressing time for high speed machines and also for papers with higher basis weight made from highly beaten stock. As speed is increased higher nip loading will be required to maintain same moisture removal or for the same nip loading water removal from the sheet will decrease with increased speed. With the increase of speed press performance will be less tolerant to dirty and filled felts. At higher speed it will be necessary to change the angle of the felt leaving the nip to avoid rewetting (Clark, 1996).

(c) Roll parameter: Open area, type of perforations, roll diameter, rubber hardness and thickness are variables which are normally fixed by the grades of paper made, the speed and the loading of the press. Water removal increases with smaller rolls and harder covers but the practical limitations of roll design and paper quality often limit the degree of improvement. Rubber hardness and diameter of rolls have got much influence on the drainage of water in the press.

(d) Off couch moisture: The dryness of the sheet leaving the press is dependent on the sheet dryness entering the press section. For economic benefits dryness at couch should be raised .

(e) Felts: The felt is not only the most important variable but a variable over which some control can be exercised. This is dealt in detail in a separate section.

(f) Sheet porosity: Sheet characteristics influence drainage. The porosity of Paper web is very important for drainage on the press. Less porous the sheet more is the tendency of crushing. Kraft pulps are very porous and elastic and then comes sulphite pulps. mechanical pulps have less porous structure. Freeness of stock can appreciably change the drainage property of the press. A press will remove more water from a free sheet than from a wet sheet at the same loading.

(g) Temperature: Increasing of pressing temperature increases drainage rate on the press. Rise in the temperature of the stock by 9^0 C increases the dryness of the paper from 2% to 3%. Affect of temperature on drainage rate during pressing is attributed to the change in viscosity of water with temperature (Lush 1997).

TYPES OF PRESSES

Several general type of wet presses are used on paper machines. Press arrangements are combination of various types. All have the primary function of water removal and secondary functions such as transfer of the web from one felt to another, smoothing the web surface or otherwise affecting paper properties.

Plain Press : It's a simple and the oldest of the presses available. The fabric and the sheet pass through the nip between the two solid press rolls. Water squeezed out at the nip flows backward, opposite to the sheet travel and the rotation of the rolls, down the surface of the bottom press roll and off into the saveall pan. The wrap of the sheet and the fabric on the top roll helps force out any air between the sheet and the fabric, preventing blowing and press wrinkles.

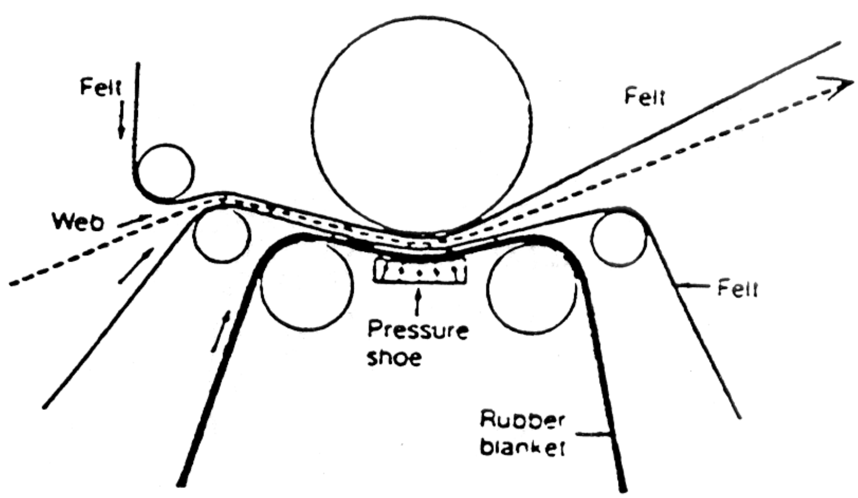
Double felted press: Double felting a nip allows water removal in both directions and can greatly increase the capacity. The greatest advantage is for heavier weight sheets and higher nip pressures. For lower basis weights and lower freeness furnishes, double felting the first nip can give some improvement in press performance and provide a more forgiving nip. They are mostly used at first presses where the greatest quantity of water is being handled and where the greatest tendency for crushing exists. These presses causes less sheet two-sidedness (Fekete, 1998).

Suction press: The suction press roll is composed of a bronze stainless steel shell usually covered with either rubber or a synthetic material such as polyurethane. Both the shell and cover have approximately 3.2mm diameter holes drilled on about 8mm centers over the entire roll surface. A non-rotating suction box fitted to the inside surface of the shell extends across the face. Air or spring loaded seals are positioned between the inside shell surface and the box. Liquid ring type vacuum pumps or centrifugal exhausters, located in the machine room basement or outside provide the vacuum. Figure 4 shows a suction press.

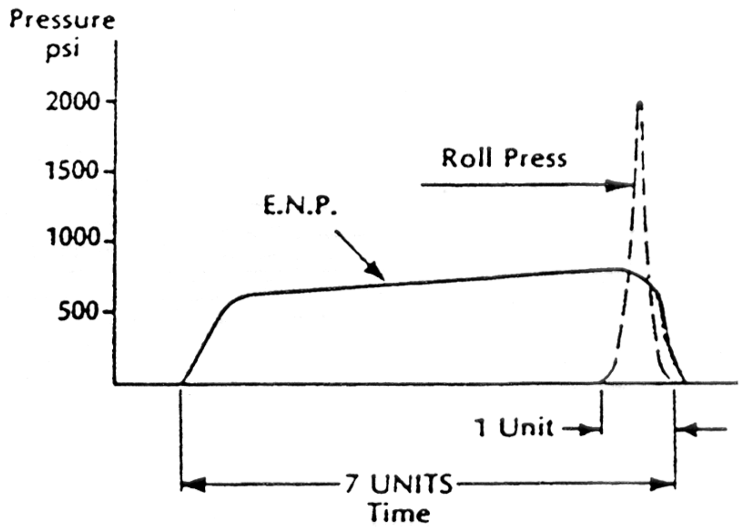
Hot press roll : The hot press roll was designed to increase sheet temperatures directly in the press nip, thus decreasing the viscosity of the water and enhancing removal. A large diameter roll is internally heated with steam or hot water or hot oil. The sheet contacts this roll directly, there by being heated at the same time that it is placed under pressure. Excellent heat transfer is achieved resulting in excellent water flow and drainage through the porous structure of the sheet and felt. This improvement provide options for increasing productivity and reducing operating costs. The principal limitation of this press type is effectiveness of the release coating of the roll. At higher roll temperatures there is increased tendency for fibres or stickies to pick or stick to the hot surface (Clark, 1997).

Extended Nip Presses

To reduce the energy costs involved in drying section of paper machine it was required that the sheet leaving the press section should have a higher dryness. Long nip presses was the answer to achieve higher dryness.

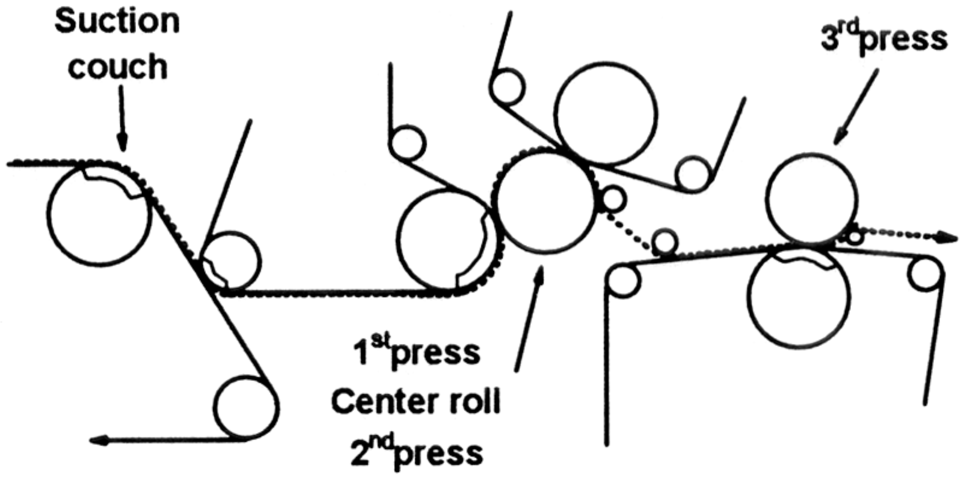


These presses consist of a press roll opposed by a stationary loaded shoe. The press is usually double felted with one felt against the top roll and the other passing through the nip surrounding the shoe and its supporting beam. With the increased dwell time (see below) of these presses a dryness of around 55% can be reached. Combination of shoe presses with other presses or using two shoe presses is becoming a common trend (Breiten, 1998). These presses are used for heavier basis weight grades.

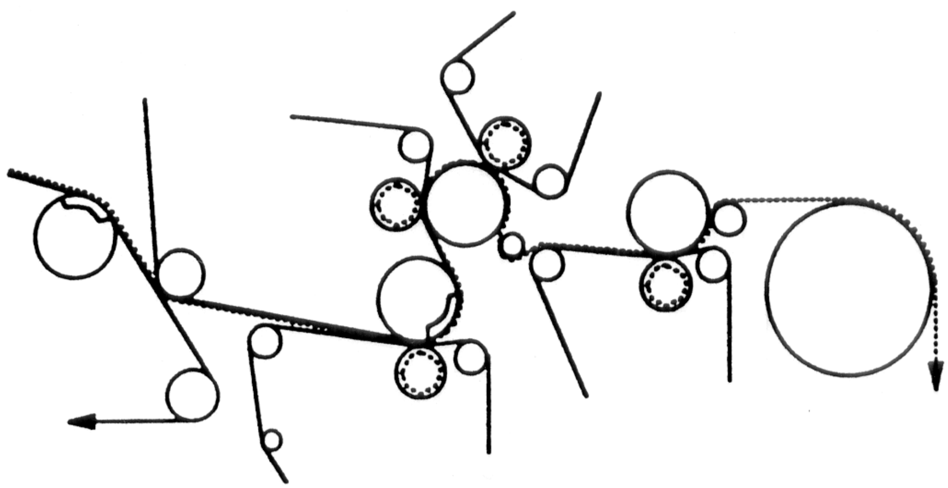


Configuration

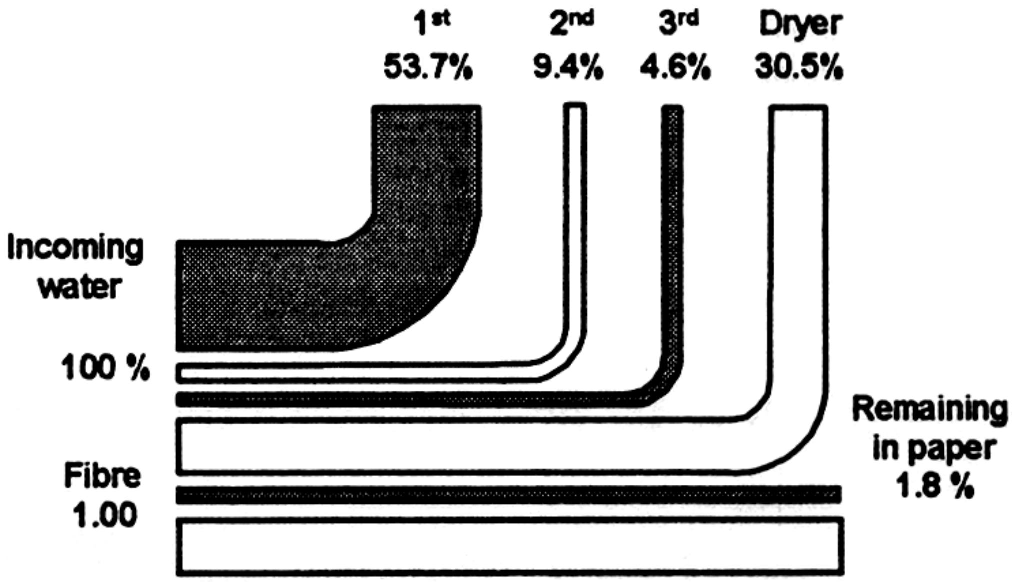
Pressing on a paper machine typically takes place in three or sometimes four press nips. The wet web is transferred to the press form the forming section by a “suction pick up” at the couch roll. In this typical three-nip press, the first nip is made up of a suction roll and granite roll with the second nip being another suction roll on the same granite roll. This is followed by a free draw, followed by a third press made up of a granite roll and suction roll.



A four-nip press is shown below. This gives both sides of the paper equal exposure to a smooth granite roll. This configuration also has a transfer roll to eliminate the free draw after the second press, thereby increasing the runnability of the paper machine.



Additional nips give diminishing returns in water removal:

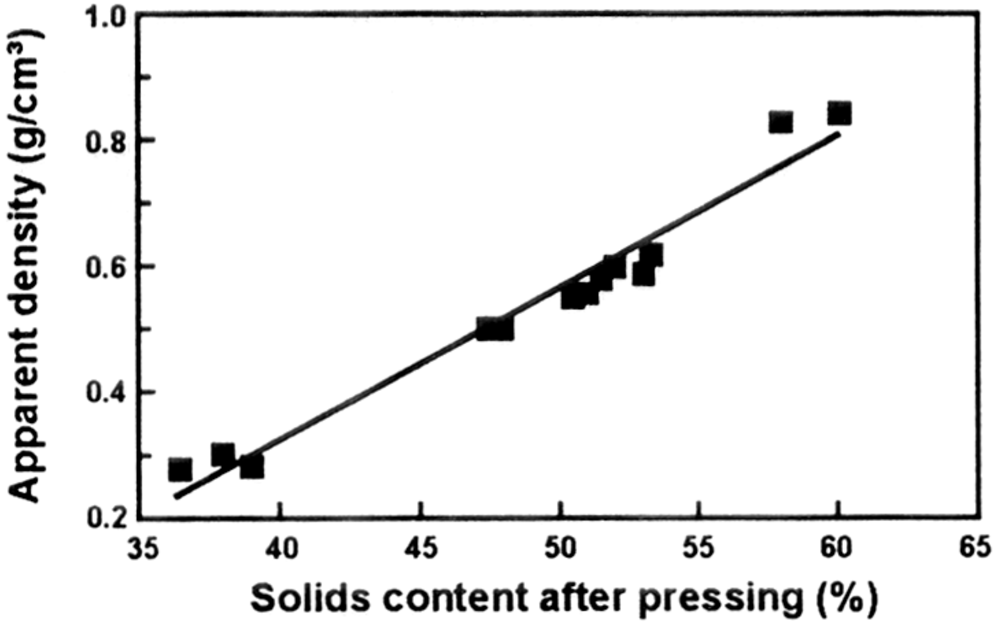

1st
53.7%
2nd
9.4%
3rd
4.6%
Dryer
30.5%
Incoming
water
100 %
Fibre
1.00
Remaining
in paper
1.8 %

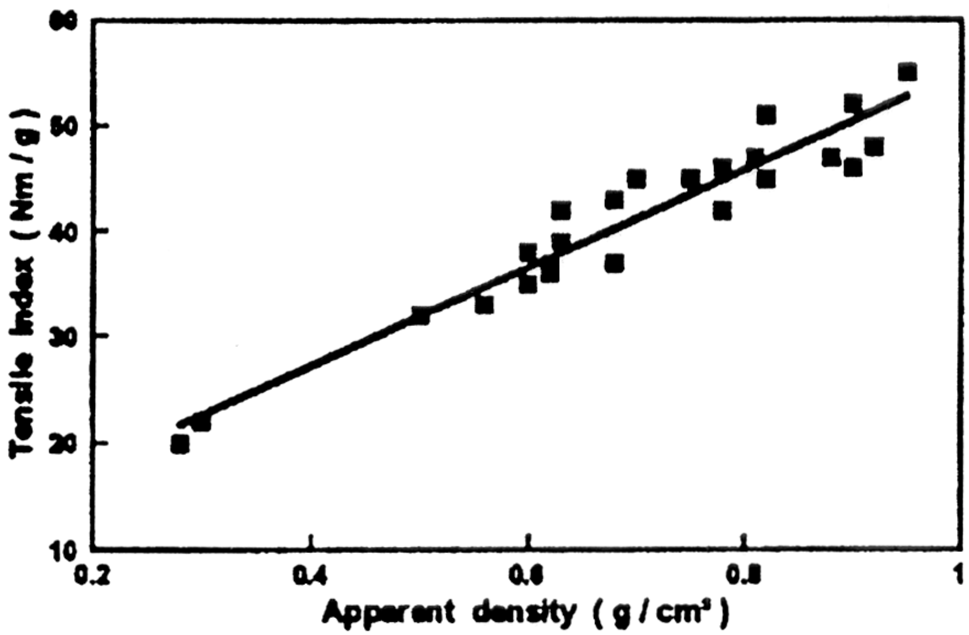
EFFECT OF PRESSING ON PAPER PROPERTIES

The wet press section not only helps in water removal but also determines some of the physical properties of paper like caliper, density, strength and surface properties (Reese, 1999). The effect of press loading on paper properties was investigated by Ivan et al using a pilot paper machine. It was found that changes in press nip loads have a small effect on the sheet bulk. Sheet bulk was increased by unloading the first press than by unloading the fourth press. Higher press nip loads increased internal bond strength but had only a small effect on tensile, burst and tear strength. The print quality was enhanced more by increasing the load of the first press than that of the last press. The paper side exposed to the press felt in the last-press nip tended to be rougher, and the roughness increased with nip load. Print quality was improved on the paper side that contacted the felt in the first-press nip. No significant movement of filler in the sheet thickness is observed even under extreme pressing conditions.

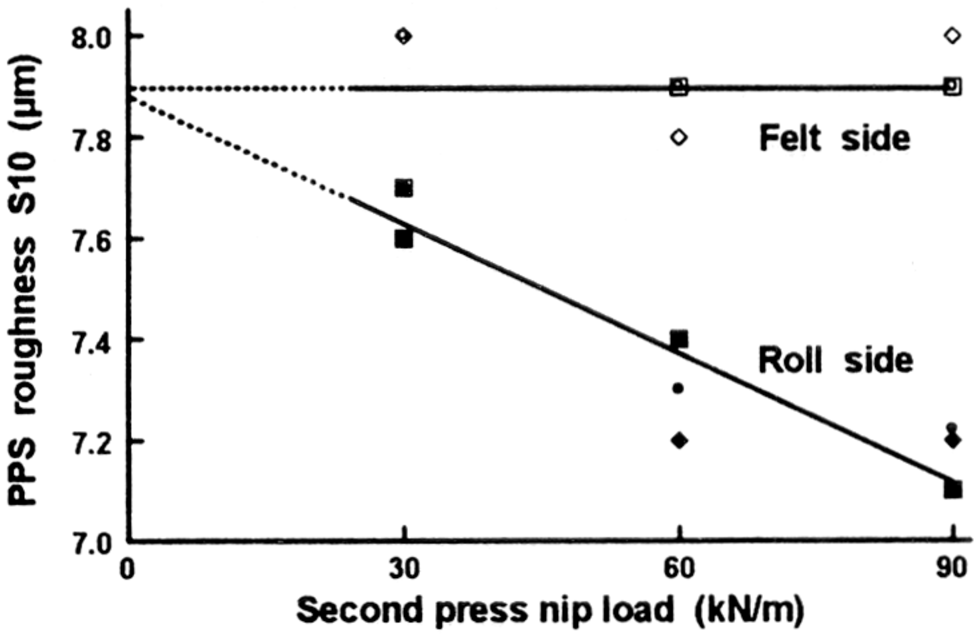
Bonding between fibres begins at approximately 22% solids and increases with increasing solids content (Reese, 1999). Therefore tensile, burst and stretch increases with increasing solids content. Wet pressing directly affects paper density and reduces caliper. Apparent density is the single most important factor in determining the physical properties of a paper grade produced.

Ivan et al (1998) also studied the effect of pressing on newsprint using the same pilot paper machine having four nips. Increasing the loading of either the first or fourth press to a critical value increases the strength of newsprint. Strength will decrease if the loading is increased beyond the critical value. The print density index of the sheet is directly related to the consolidation of the sheet in the press section and the calender.





Pressing also causes two-sidedness when one side of the paper is in contact with a felt and the other is not. The difference in surface roughness between two sides of paper is illustrated in Figure 20. Fourth presses are often installed to eliminate this.



PRESS FABRICS

The primary function of press fabric is to provide resilient, permeable support for the sheet in the nip to maximize water removal. The press fabric transfers mechanical pressure from the rolls to the sheet to drive water removal and void volume to receive water expressed from the sheet. The fabric also conveys the wet web through the press section and provides transmission to turn rolls in the fabric run (Reese, 1999).

The primary materials used in the manufacture of press fabrics are polyamides. Polyamide fibers and yarns are purchased in various sizes and with different specifications for properties such as tensile and degree of pre-shrinkage. The specifications chosen depend on end use. Polyamide fiber is durable, strong and resistant to wear, hence it has rapidly replaced wool in most press fabric applications. The important properties of press fabrics to be considered are stiffness, void volume, compressibility, hardness, permeability, caliper and basis weight (gsm), tensile and elongation, surface uniformity and abrasion.

The efficiency of a press section depends on the press fabric. As the fabric takes water from the paper nip it has to be dewatered before presenting itself again to the nip (Robert, 1996). Due to high speeds of machines vacuum boxes are used to dewater the fabrics. It is necessary to keep the felts clean and prevent it from filling as the felt picks stickies, fillers and fibres as it comes in contact with the paper (Summer, 1998). This is accomplished now a days by continuous online cleaning of felts. Monitoring the permeability of felt on line helps in overcoming many sheet properties. Now a days all the press fabrics on high speed machines have the cleaning system. Otherwise previously it needed a shut down to clean the felts (Antos, 1998).

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