Pulp Washing on Double Wire Presses

Singh S.P.

INTRODUCTION

Rotary drum vacuum filter is the principal pulp washing equipment in Indian pulp and paper industry. Multistage counter current washing systems based on such filters are very well suited to the batch pulping processes prevalent in India. They are quite acceptable for washing of wood or bamboo pulps. However; these washing systems give lower capacity per unit surface of the filter for agriresidue pulps due to poor drawing characteristics of these pulps.

Bhasker et al. (1) have observed that a double wire press can be used for efficient washing of agriresidue pulps. A schematic diagram of the washing system used by Bhasker etal. has been shown in Figure-1. The pulp is formed into a mat of about 15% consistency and then a multistage counter current washing of the mat without reslushing it between the stages is attempted. This is expected to reduce the requirement of pumping large volumes of dilution liquor between the stages. Since no drop legs will be required, the pumping heads would be smaller than those in a vacuum filter washer resulting in large savings in pumping energy. But whether the double-wire press systems provide any effective displacement washing is not well established.

In the present analysis an attempt has been made to critically review some of the claimed advantages of a double wire press based wasing system over a rotary drum filter based system.

SPECIFIC PRODUCTION RATE

A double wire press appears to offer an advantage of having a greater specific production rate than a vacuum filter as it uses mechanical compression of the pulp mat to squeeze the liquor out rather than relying solely on hydraulic pressure on the liqour for its removal. The rate of dewatering will primarily depend on the external pressure on the mat applied either by increasing tension in the wires or by increasing the nip load between the press rolls. However, the maximum dewatering rate will depend on the characteristics of pulp and liquor so that a stable mat can be formed avoiding crushing.

Bhasker et al. have observed a much greater specific production rate on double wire press than on a rotary vacuum filter as shown in the columns 2 and 3 of Table-1, However, the values have been

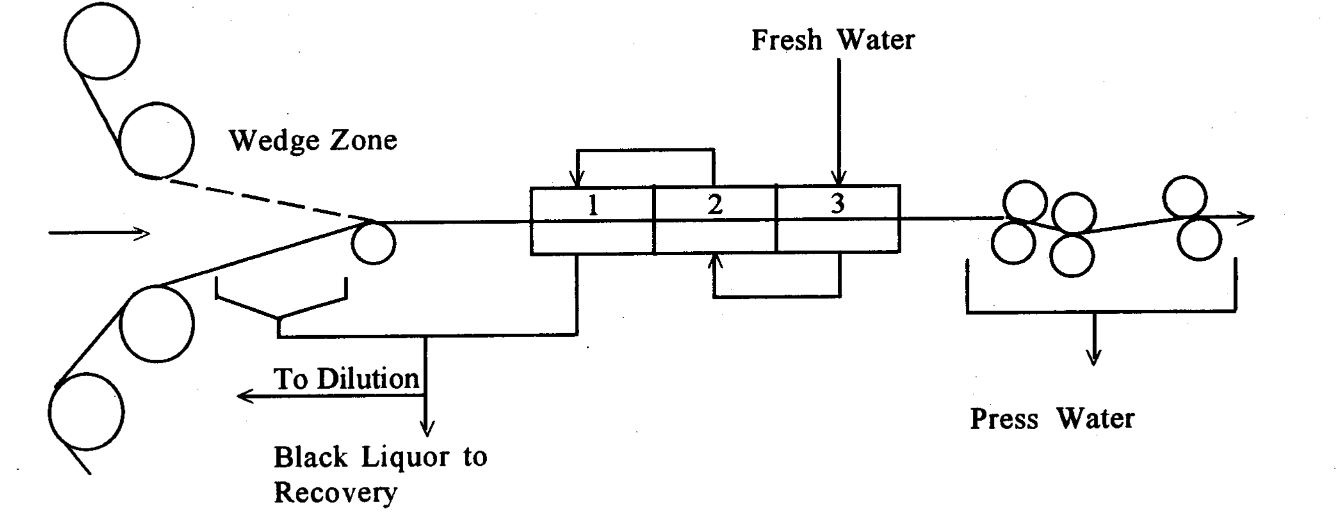

Figure-1: Schematic diagram of a double-wire press washing system

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SAHARANPUR-247 001 (INDIA)

reported in different units and when converted to the identical units as given in column 4 of Table-1, the difference is not as dramatic as suggested

THE WASHING EFFECT

The main objective of wasing pulp is to ensure that a minimum of dissolved solids accompany the pulp when it leaves the pulping section to subsequent processing steps. This is to ensure that energy and cooking chemicals are efficiently recovered, the consumption of bleaching chemicals is kept low, and the pollution loads on the effluent stream are minimized. A part of the objective is achieved if the quantity of the liquor accompanying the pulp flow is reduced. Further washing can be achieved by displacing with fresh water the accompanying liquor in the pulp.

Table-1

Specific Production Rates on Rotary Drum Filter Washer and Double Wire Press (1). Values in column 4 obtained by dividing the values of column 3 by the length of the wire, i.e., 9.26m.

Pulp Type 1	Rotary Drum Filter, t/m².day 2	Double Wire Press, t/m.day 3	Double-wire Press, t/m².day 4
Bamboo	3-5	--	--
Bagasse	2-4	31.3	3.38
Rice Straw	1-2	22.4	2.43
Wheat Straw	1-2	22.5	2.44

EFFECT OF DEWATERING ON WASHING EFFICIENCY

A dewatering unit such as a double wire press should result in a high washing efficiency simply because it discharges the pulp at a very high consistency (approx. 30%). Let us consider a schematic diagram of a dewatering process shown in Figure-2.

For a dewatering operation:

$$X_0 = X_1 = Y_1 \qquad [1]$$

$$W_1 = L_0 - L_1 \qquad [2]$$

and the washing efficiency

$$\begin{aligned} E &= 1 - (L_1.X_1/L_0.X_0) \\ &= 1 - (L_1/L_0) \\ &= (1 - C_0/C_1)/\ (1-C_0) \qquad [3] \end{aligned}$$

Where,

X = Concentration of liquor accompanying the pulp, kg dissolved solids per kg liquor.

Y = Concentration of separated liquor, kg dissolved solids per kg liquor.

L = Liquor flow, kg/kg pulp.

W = Liquor accompanying the pulp, kg/kg pulp.

C = Consistency of the pulp, kg fibre/kg pulp slurry.

The effect of discharge consistency, C_1 on the washing efficiency of a dewatering unit is shown in

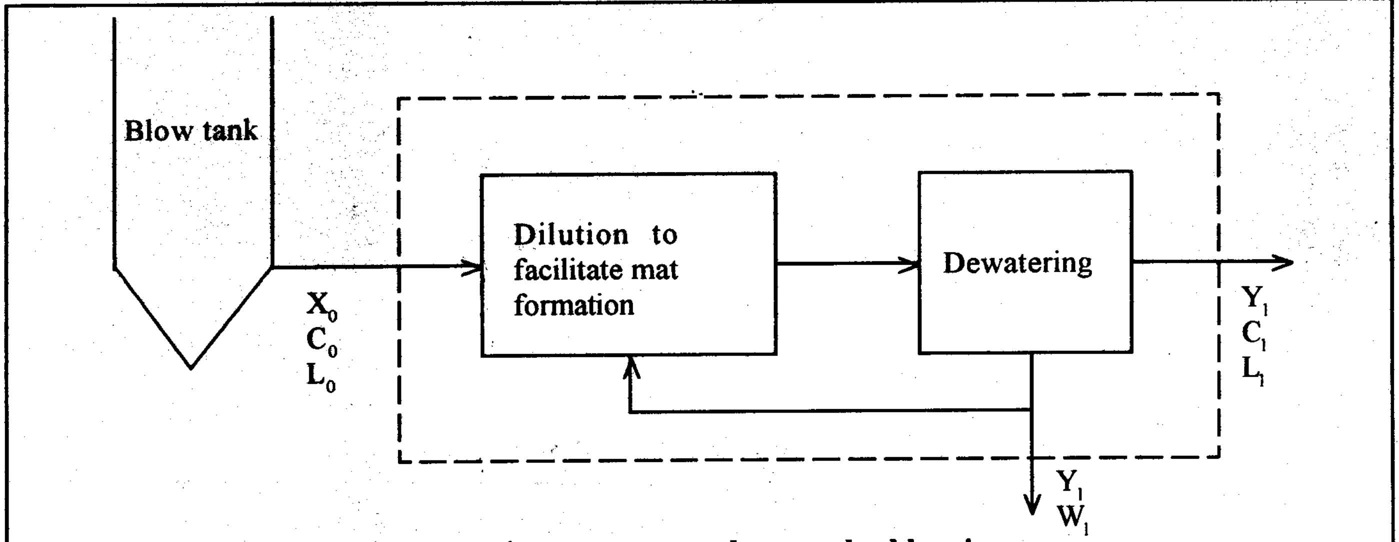

Figure-2: Principle of dewatering systems such as a double-wire press

Table-2. It can be seen that dewatering to a high consistency alone is capable of giving higher washing efficiencies.

Table-2

Washing efficiency calculated using equation [1] at different values of C_0 and C_1

	Washing Efficiency	
C_0	C_1 = 0.30 Typical discharge consistency from a double wire press	C_1 = 0.12 Typical discharge consistency from a rotary vacuum filter
0.02	95.24	85.03
0.04	90.28	69.44
0.06	85.11	53.19
0.08	79.71	36.23
0.10	74.07	18.52
0.12	68.18	00.00
0.14	58.82	--
0.16	41.67	--

DISPLACEMENT WASHING

It has been suggested that the double wire press can be used for displacement washing of the pulp. A mat formed once is washed in a number of counter current displacement stages without diluting it between the stages. Typical washing systems have been schematically shown in Figure-3 and Figure-4.

As shown in figure-3, three options exist for the water expressed out in the second dewatering stage.

a) The expressed water is recycled in the system possibly by adding with the fresh water.

b) The expressed water is discarded. In the latter case the second stage dewatering has no effcet on washing efficiency as far as the recovery of energy and chemicals is concerned, but the pulp going to subsequent processing is cleaner

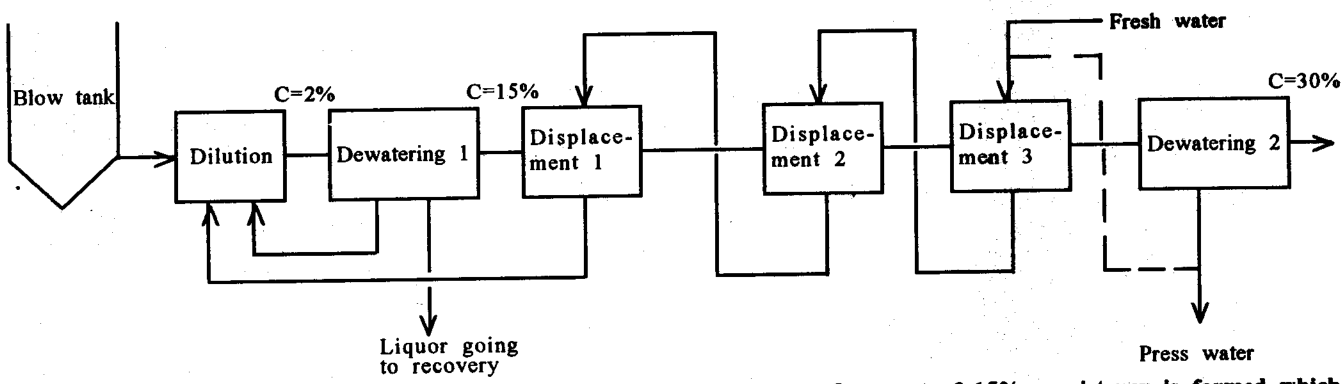

Figure-3: Three-stage washing on a double-wire press. In dewatering stage I, a mat of 15% consistency is formed which is then washed in three counter-current displacement washing stages. The final discharge consistency is increased to 30% in the dewatering stage 2.

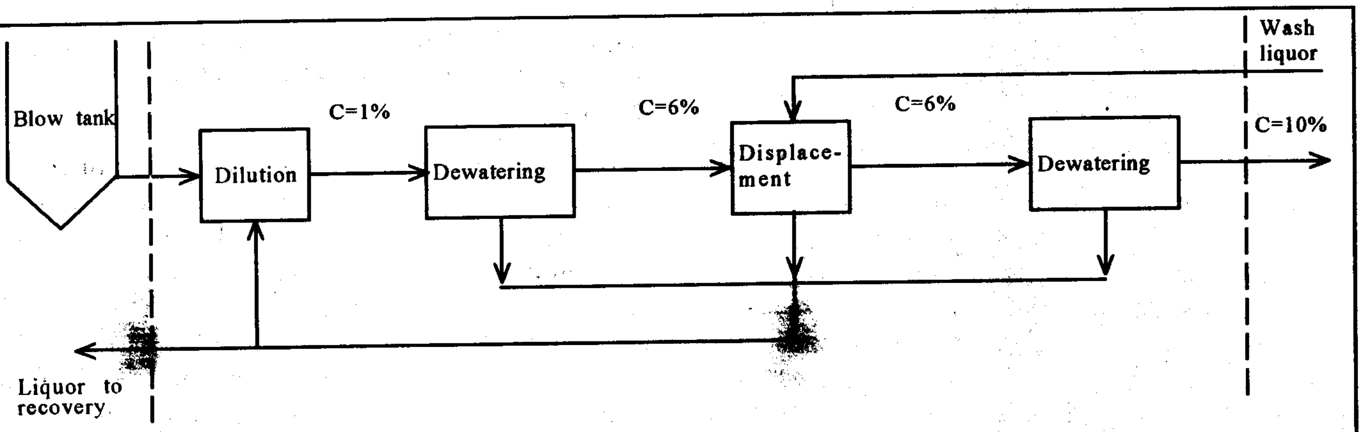

Figure-4: Single stage of a counter-current washing system based on rotary durm vacuum filters because it is carrying less amount of impure water.

c) Water expressed out from the second stage dewatering may be used in some other process, for example, in white liquor preparation.

Table-3 Shows a comparison of washing systems shown in Figure-3 and Figure-4. The washing efficiencies have been calculated using mass balance equations assuming complete equilibrium at each dilution stage. Displacement ratio of a washing stage depends upon the dilution factor, the consistency of the mat, diffusivity of the dissolved solids, and presence of foam in the pulp. In the present example, values of displacement ratio have been calculated using the Cullinan's equation (2).

$$DR = 1 - \exp \{ - E (1 + DF / L)\} \quad [4]$$

Where E is stage efficiency dependent on the rate of diffusion of dissolved solids, and the presence of foam in the pulp. DF is the dilution factor. In these example calculations the value of E has been taken as 1.2.

Table-3

Typical values of Displacement Ratio calculated using Eq [4]

DF	Rotary drum filter washer Washing at 8% consistency	Double wire press washer Washing at 15% consistency
0	0.609	0.699
1	0.648	0.756
2.	0.683	0.803
3.	0.714	0.840

Table-4 shows that the displacement washing at greater mat consistency in a double-wire press is more efficient than that at lower consistency on rotary drum vacuum filters for the same dilution factor and number of stages. Recycling of the last stage dewatering water gives slightly better recovery efficiency values but the system with no recycle gives markedly cleaner pulp as shown in Table-5.

Table-4

Washing Efficiency for three different washing systems

Blow tank consistency = 10% (assumed)

Number of stage	DF kg/kg	Rotary drum filter	Double wire press PW recycled	Double wire press PW not recycled
3	0	88.10	93.71	92.67
	1	92.36	97.22	96.43
	2	95.23	98.82	98.35
	3	97.36	99.51	99.26
2	0	83.15	91.82	89.96
	1	87.44	95.93	93.85
	2	90.72	97.43	96.31
	3	93.19	98.57	97.81
1	0	71.15	88.29	84.06
	1	75.14	91.62	87.86
	2	78.57	93.96	90.78
	3	81.51	95.62	92.99

Table-5

A comparison of dissolved solids going with the washed pulp with and without recycling of last stage filtrate (Figure-3).

		Total dissolved Solids going with the pulp, g/kg fibre	
	DF	Recycling	No recycling
CO = 5%	0	46.20	22.42
No. of stages = 3	1	21.15	11.27
	2	9.30	5.39
	3	4.05	2.48

HOW MUCH LIQUOR CAN FLOW THROUGH THE PULP MAT DURING DISPLACEMENT WASHING STAGE

In the above calculations it was assumed that whatever amount of wash liquor was used in displacement washing stage all of that flowed through the mat without any short circuiting. Let us have a closer look at the surface area allowed for displacement, whether it is enough for the desired wash liquor to flow through the mat in a double-wire press washing system or not. An approximate analysis of this aspect can be made using Kozeny's modified Darcy's Law equation. The superficial velocity of a liquor flowing through a porous bed of particulate material is given by.

$$u = Q/A = (1/K\,S^2)\,.\,e^3/(1-e)^2\,.\,(-\Delta P)/\mu t \qquad [5]$$

Where,

u = liquor velocity, m/s

e = bed porosity

μ = viscosity of liquor, Ns/m^2

$-\Delta P$= pressure drop across the bed, N/m^2

t = bed thickness, m

S = specific surface of the particles forming the bed, m^2/m^3,

K = kozeny's constant which depends on the nature of the particles.

If it is assumed that the pulp mat always remains saturated with liquor in the washing stage, the bed porosity can be easily evaluated in terms of consistency of the pulp.

$$e = (1-C)/\,[(1-C) + d_l/d_p\,C] \qquad [6]$$

Where,

d_l = density of liquor, kg/m^3

d_p = density of particles, kg/m^3

C = consistency of bed, kg solids per kg bed mass.

Similarly the bed thickness can be determined in terms of porosity and grammage of the mat.

$$t = W/\,d_p\,(1-e) \qquad [7]$$

Where,

W = mass of the mat, kg/m^2

Liquor velocities in the washing zone of a typical rotary drum vacuum filter washer and a double-wire press calculated using equations [5], [6] and [7] are given in Table-6.

It can be seen from the Table-6 that the maximum amount of liquor which can flow through the mat consisting of unit mass of fibres is much less in double-wire press than in rotary vacuum filter.

CONCLUSIONS

1. Agriresidue pulps, due to their poor drainage characteristics, give low wash plant productivity on rotary drum vacuum filter based washing

Table-6

Calculated liquor velocities in the washing zone

S. No.		Rotary drum filter	Double-wire press
VALUES ASSUMED			
1.	Liquor density, kg/m^3	1000	1000
2.	Liquor viscosity, Ns/m^2	$1x10^{-3}$	$1x10^{-3}$
3.	Fibre density, kg/m^3	1500	1500
4.	Mat consistency during washing	0.08	0.15
5.	Mat porosity,	0.945	0.895
6.	Permeability factor, (1/KS^2), m^2	$1.52x10^{-15}$	$1.52x10^{-15}$
7.	Pressure drop, N/m^2	$40x10^3$	$4x10^3$
8.	Specific washing rate, t/m^2.day	1.5	2.43
	Specific washing rate, kg/m^2.s	0.01736	0.028125
9.	Mass of pulp mat, kg/m^2	0.7	0.7
10.	Fraction of filter area used for washing	0.25	0.05
VALUES CALCULATED			
1.	Mat thickness, m	$8.485x10^{-3}$	$4.444x10^{-3}$
2.	Liquor velocity, m/s	$1.999x10^{-3}$	$8.896x10^{-5}$
3.	Wash liquor flow, m^3/kg fibre	$2.88x10^{-2}$	$1.581x10^{-4}$
	Wash liquor flow, kg/kg fibre	28.8	0.1581

Table-7

Comparison of multistage counter-current washing systems

Blow tank consistency = 10% (assumed)

Number of stages	DF kg/kg	Multistage system based on double-wire press	Rotary drum filter
3	0	92.05	88.10
	1	95.04	92.36
	2	96.74	95.23
	3	97.77	79.36
2	0	88.50	83.15
	1	91.23	87.44
	2	93.09	90.72
	3	94.40	93.19
1	0	79.50	71.15
	1	81.08	75.14
	2	82.50	78.57
	3	83.72	81.51

systems. A double-wire press gives a higher production per unit equipment surface.

2. It has been suggested in the literature that a single unit of double-wire press can be used for multistage counter-current washing of pulp in a manner similar to that employed in belt washers like an Ultra washer. However, a close analysis reveals that a double-wire press has a severe hydraulic limitation as far as displacement type of washing is concerned. As seen from Table-6 the maximum amount of liquor that can be used for displacement washing in double-wire press is 0.158 kg/kg fibre. Assuming discharge consistency as 30%, at least 2.33 kg of liquor per kg fibre are required for a zero dilution factor.

3. A washing system consisting of two to three double-wire presses arranged in a counter-current flow of pulp and liquor offers excellent washing efficiencies. A comparison of washing efficiencies of double-wire press systems with rotary filter based systems is given in Table-7. The greatest advantage is that these machines can dewater pulp from consistency 1-2% to 30% or more. Mixing of wash liquor with the pulp at low consistency facilitates quick and near complete diffusion of dissolved solids and a high discharge consistency enhances the liquor recovery.

REFERENCES

1. Bhaskar, S., Jain, R.K., Bohidar, P.R., and Mohindru, V.K., "Application of double-wire belt washer concept for efficient washing of agriculture residue pulp", IPPTA seminar, New Delhi (1989).

2. Cullinan, H.T. Jr., Harper, F.D., and Parker, P.E., "On efficiency of brownstock washing on rotary filters", Pulp washing symposium, Helsinki, pp101-111 (1987).