Design of Concentrator Systems For Indian Raw Materials

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SUMMARY

The raw materials most commonly used in Indian paper industry are bamboo and hard wood. The other raw materials like bagasse, rice straw etc are also finding their increasing use due to depletion of the forests.

The characteristics of black liquor depend largely on the raw material used and the cooking process. The evaporation of black liquor is a bottleneck in the chcmical recovery sections of many paper mills. The evaporation in higher concentration range requires the use of Forced Circulation Concentrator.

The design and performance of the FC concentrator is greatly influenced by the thermal and rheological characteristics (like BPR, viscosity and specific heat) and the constituents (like silica, organics, inorganics and Na_2O contents) of the liquor. The concentrator can also be coupled with the existing multiple effect evaporator to increase the capacity and decrease the downtime of the whole evaporator system.

INTRODUCTION

Until late sixties bamboo was the major raw material in Indian paper industry. The recent, rend is, however, to use more and more hardwood to conserve bamboo forests. The other raw materials like bagasse, eucalyptus and straw etc. are also finding their increasing use for paper production.

Most of the evaporator plants supplied prior tc late sixties were designed for bamboo furnish black liquor. The use of hardwood has further deteriorated the evaporator performance due to different liquor characteristics. Many paper mills have experienced a reduction in the capacity of the evaporator after switch ng over to mixed hardwood and bamboo pulping. The evaporators which were designed for bamboo black liquor for a product of 50% TS are now giving only 40-45% TS. Some of the evaporators are operating at capacities as low as 50% of the design capacity. The two main causes for the poor performance of evaporators are as follows :

(i) Use of hardwood for pulping
(ii) Scale formation over the years of operation

The black liquor evaporator is, thus, a bottleneak in achieving the desired paper production. Moreover, due to the increase in the demand of paper, the expansion of the existing mills is inevitable.

The deficiency in the capacity of the old evaporator can be overcome by installing a Forced Circulation Concentrator. When the concentrator is coupled with the existing unit, the product from the latter may be withdrawn at a lower concentration and fed to FC concentrator for further concentration. The addition of a concentrator to the evaporator system may decrease the steam economy to some extent but the capacity and the cleaning cycle of the whole system would improve considerably.

The design of FC concentrator is based on the liquor characteristics and the heat transfer data of the existing system. After evaluating the performance of the existing system, the concentrator is designed by simulating the plant data on computer.

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LIQUOR ANALYSIS & CHARACTERISTICS

The chemical analysis and the characteristics of black liquor depend upon the raw material used and the digestion process. The liquor properties, in turn, greatly influence the design and performance of the concentrator.

Extensive investigations on the analysis and thermal and rheological properties of the black liquor from different raw materials were done in our bench scale. These results along with the heat transfer data from pilot plant studies form the basis of concentrator design,

Chemical Analysis

Black liquor is essentially a mixture of organic and inorganic compounds. The organic components are lignin, pentosans. cellulose etc. and the inorganic constituents are silica NaOH, Na_2SO_4, Na_2CO_3 etc.

Table I gives the analysis of black liquor samples obtained from four different sources, namely, hardwood, bamboo, mixed hardwood (40%) and bamboo (60%), and bagasse. Silica is highest in bamboo black liquor. Silica in liquor comes from bamboo and the make-up chemicals like salt cake and lime. Higher is the silica content higher would be the hard silicate scale formation in the evaporator handling liquor at high concentration and temperature. The orgnic and inorganic constituents increase the viscosity and boiling point rise and decrease the specific heat of the liquor. A high NaOH content would mean lower viscosity of the liquor. The higher NaOH content also keeps the silica in solution and prevents it from precipitation. A higher organic content (e. g. in hardwood liquor) would mean higher viscosity of liquor. Hardwood liquor poses problems due to organic solids precipitation. The deposit is gummy black carbonecous matter which can be removed by water boiling.

TABLE—1 ANALYSIS OF INDIAN BLACK LIQUORS

S. No.	Particulars	Hard-wood	Bam-boo	40% Hard-wood + 60% Bam-boo	Baga-sse
1.	Silica as SiO_2, gpl	0.97	1 25	1.07	0.95
2.	Na_2SO_4 as	4.7	4.4	1.8	0.85
3.	NaOH as Na_2O	3.9	4.3	6.6	5 90
4.	Na_2CO_3 gpl	16.5	21.0	8.7	35.5
5.	Na_2S	0.4	2.8	1.05	3.10
6.	pH	10.5	11.0	11.5	11.0
7.	Organic: Inorganic ratio	55:45	46:54	55:45	44:56

Thermal & Rheological Properties

The liquor properties which effect the design are viscosity, boiling point rise, specific gravity, specific heat and thermal conductivity. Out of these, the first two have been considered here which play a dominating role in the system selection and design.

Viscosity

Viscosity is one of the most important liquor characteristics upon which depends the liquor flow routing, design and selection of chemical equipments and the heat transfer coefficients in the bodies. It sets a limit to the maximum concentration that can be achieved in the LTV evaporator. It is greatly influenced by the furnish. Figure I gives the viscosity of the liquor from different sources. The viscosity of bagasse liquor is highest in the entire concentration range. Bamboo liquor has the lowest viscosity. Hardwood liquor is more viscous than bamboo liquor. Mixed hardwood and bamboo furnish produces liquor which is more viscous than bamboo liquor but less viscous than hardwood liquor.

VISCOSITY OF BLACK LIQUORS

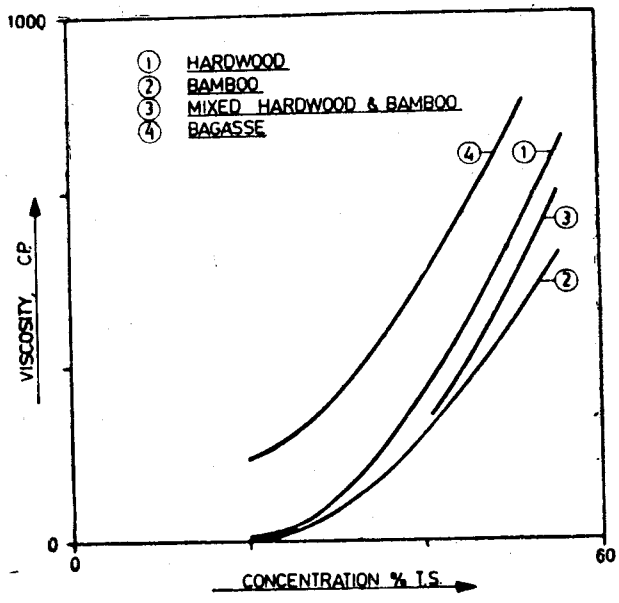

Fig-1

The viscosity decreases with temperature and increases with concentration. At high concentration and low temperature the black liquor becomes Non-Newtonian. During Non-Newtonian behaviour the viscosity decreases with the shear rate. This indicate its pseudoplastic nature. Our experience indicates that if the viscosity is below 4500 cp the liquor is Newtonian and above 5100 cp the liquor behaves Non-Newtonian.

By and large, under the temperature and concentration prevailing in the evaporator, the liquor is Newtonian.

Boiling Point Rise

The BPR is an important engineering property which effects the driving force across the evaporator. It is a function of liquor concentration, pressure and is greatly influenced by the furnish. The BPR has been plotted as a function of concentration for liquors from 4 sources in figure 2. The bagasse raw material produces liquor of highest BPR. The bamboo liquor has relatively low BPR. The hardwood and bamboo liquor has BPR higher than that of pure hardwood.

BOILING POINT RISE OF BLACK LIQUORS

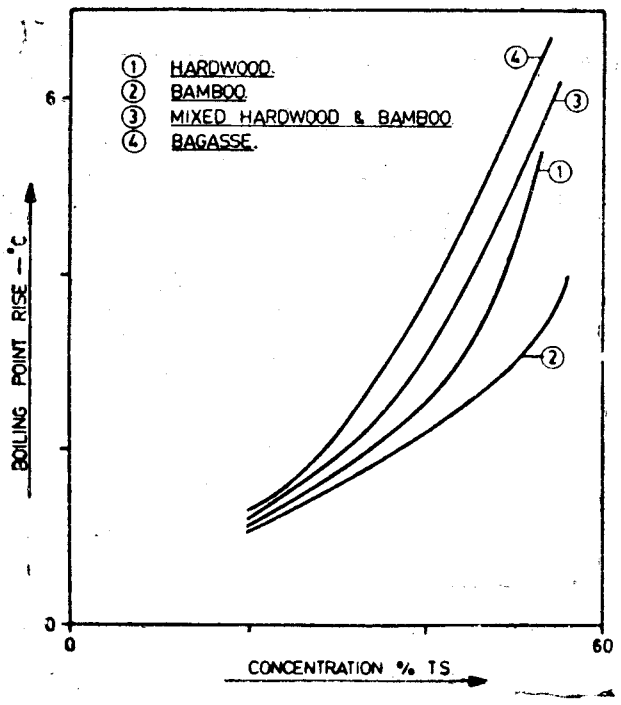

Fig.2

Forced Circulation System

The concentration of black liquor above around 40% TS necessitates the use of FC concentrator due to the problems of viscosity and silica/organic precipitation at higher temperature in LTV evaporator. With the concentrator of correct design, assuming sufficient circulation and operation at correct temperature, no difficulty would be encountered from precipitation at high concentration.

FORCED CIRCULATION CONCENTRATOR

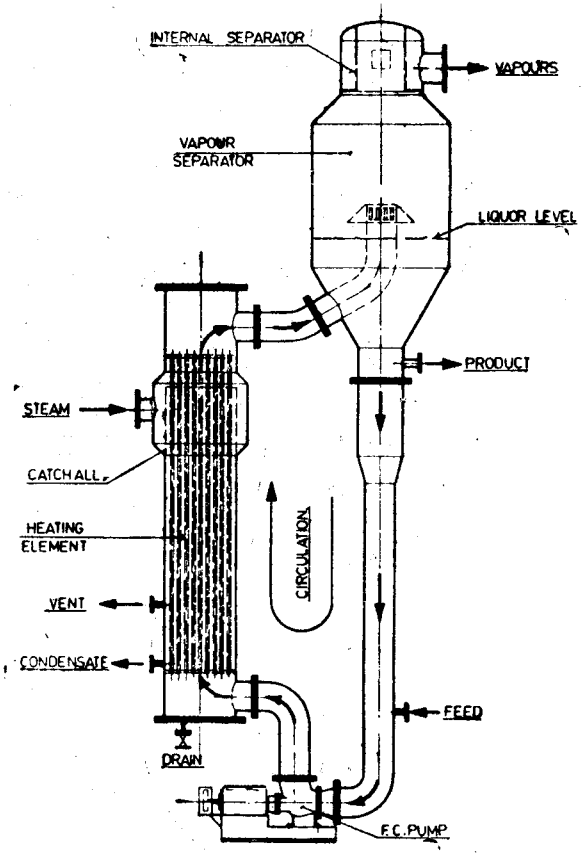

Fig-1

By withdrawing the liquor from the existing system at a lower concentration and feeding it to FC concentrator, the availability of the system is increased considerably. This would considerably improve the cleaning cycle.

SYSTEM DESCRIPTION

The 3 main divisions of FC concentrator are heating element, a vapour separator and the

circulation system. The black liquor leaving LTV evaporator enters the system through liquor inlet nozzle and mixes with liquor circulated inside the system. The circulation pump forces the liquor into the liquor box where it is distributed uniformly among the tubes. Liquor flowing up through the system is heated by steam which condenses outside the tubes. The catchall helps in distributing the steam uniformly in the shell. The steam condensate is flashed along with the steam condensate from the first effect. The vapours from 1st effect can also be used as a heating medium. The liquor leaving the tubes flows into the vapour separator through upper liquor chamber and circulation pipe. The superheated liquor which enters the separator through a "pagoda" deflector is flashed in the separator and gets concentrated. The concentrated liquor flows down the vapour body into circulation pipe. The product is withdrawn from the system before the feed entry point. The vapour, entrained with black liquor rises and enters a centrifugal separator where liquor is separated and is drained into the bottom of vapour separator. The vapours leaving the concentrator are added to 3rd or 4th effect calandria of the existing evaporator.

FC Pump

The circulation rate is maintained by a high capacity low head pump. The circulation rate is independent of concentration or foaming properties over a wide range of operating conditions. Such a pump falls under axial flow region. If multipass heating element is used a centrifugal pump has to be used for circulation. Table 2 gives the typical capacities and TDH requirements for FC pumps for heaters of different passes. For single pass heating element pump comes under axial flow range. For 2 passes, pump comes under mixed flow range. When number of passes is 4 or more centrifugal pump is required for circulation.

TABLE—2 FC PUMP CHARACTERISTICS

S. No.	Particulars	Capacity, m^3/hr	TDH m	Range of pump
1.	Single pass heater	2150	5.5	Axial
2.	2-pass heater	1075	10.5	Mixed
3.	4-pass heater	537.5	18	Centrifugal
4.	6-pass heater	360	25	Centrifugal

Features of FC System

i) The upper limit to steam pressure in the heating element is set at 40 psig. The pressure higher than this is likely to cause tube-side scaling due to higher temperature.

ii) An optimum velocity of 7-12 fps is maintained in the tubes.

iii) Sufficient hydrostatic head is maintained above the heating element to prevent the liquor from boiling in the tubes.

iv) The entrainment is reduced due to positive action of the high velocity downward curtain of the liquor when it exits in the separator and also due to high efficiency internal centrifugal separator near the vapour exit.

CONCLUSION

The forced circulation concentrator offers the following advantages over the LTV evaporator for high concentration range :

i) Larger operating cycles

ii) Higher heat transfer coefficient due to higher liquor velocity.

iii) Scale formation drastically reduced due to rapid circulation.

iv) Negligible maintenance when SS tubes are used.

v) Ease of handling foaming liquors

vi) Can handle wide variations in the feed flow rate and concentration.

When the concentrator is compounded with the existing black liquor evaporator, the overall steam economy may decrease slightly but the capacity of the system and its operating cycle would increase considerably. By simulating the heat transfer data on computer, the effect of FC concentrator on process parameters like steam economy etc. can be predicted.