Determination of Batch Digester Pulp Yield

Singhal D.K. & Singhal Swati (MRS.)

ABSTRACT: The pulp and paper making process involves many complex unit operations and unit processes. Due to existing condition of low profitability, increasing energy prices etc., there is an enormous pressure on the industry to optimize the operations involved. The batch operations normally can be optimized easily by means of discrete optimization techniques, but the only requirement is the information on the process variables. For example, if we wish to optimize the pulp yield, we must be able to know what the yield was in a particular cook. For the same purpose, a mathematical model is proposed here which can be used to analyze the pulping operation and determine the unscreened, unbleached pulp yield.

INTRODUCTION

Yield in a batch digester operation is an absolutely important aspect for the analysis of performance of pulping reaction. To optimize the pulping reaction the only available technique for batch digesters is discrete optimization. The laboratory equipments are often accused of not simulating the exact mill operations. In such circumstances, the only choice with the process engineer is to make use of the information available from the plant equipments, and to use it for optimization purpose.

For the determination of yield in pulping reaction. it is absolutely necessary that the process variables as well as the output parameters are avaible for each of the cook. In most of the cases, the optimization of the pulping process is done with the objective that the pulp yield is at its maximum level while the pulp properties remain within acceptable limits. Obviously in such a case, the process engineer needs to know the actual yield obtained after the pulping is over. If seems simple to define what the yield is, but as shown later it may even be one of very difficult tasks to determine the resultant yield at the end of cook.

The present model employs the simple material balance applied over the batch digester in order to determine the pulp yield.

MODEL

The digester can be considered to be a black box, in which a part of the raw material charged as input (lignin etc.) is converted to some other form (black liquor) and the inputs after processing come out with a different state of material combinations. This black box model is shown in figure-1.

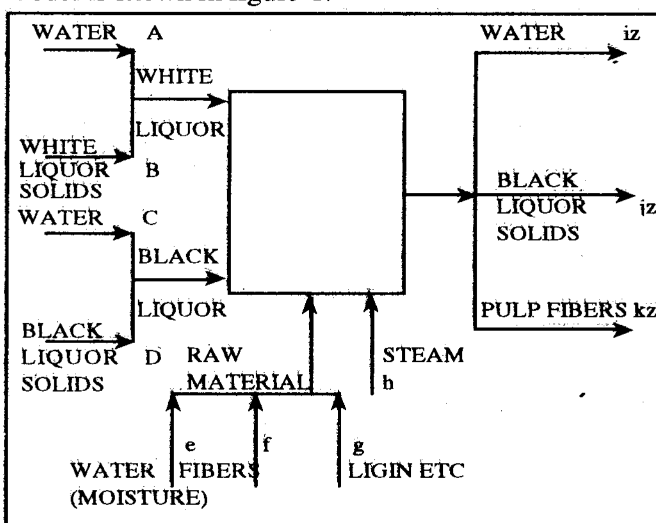

Figure-1 The Black Box Model of Digester

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Probably, the most significant part of the model is the raw material stream. In this model, we may assume that there are three components of raw material, namely-

1. Water in the form of moisture. (e)
2. Fraction which comes out in form of fibers or pulp after pulping. (f)
3. Fraction which is converted into black liquor solids during pulping. (g) Its main components are lignin, some amount of hemicellulose, pentosans etc. For simplicity, it has been written as `lignin etc.' in figure.

Here, Z is taken as a proportionality constant, the value of which is the inverse of fraction of pulp slurry (unwashed) taken for sampling.

From the diagram itself, we can see that it is a problem of 12 variables. To get the values of all of the variables, we have the following 12 equations-

$$\frac{b}{(a+b)} X\ 100 = \text{known} \qquad (1)$$

$$\frac{d}{(c+d)} X\ 100 = \text{known} \qquad (2)$$

$$a + b = \text{known} \qquad (3)$$

$$c + d = \text{known} \qquad (4)$$

$$\frac{e}{(e+f+g)} X100\ X_1 (\text{Say}) = \text{known} \qquad (5)$$

$$a+c+e+h = i\ X\ z \qquad (6)\ \text{water balance}$$

$$b+d+g = j\ X\ z \qquad (7)\ \text{solids balance}$$

$$f = k\ X\ j \qquad (8)$$

$$i = \text{known} \qquad (9)$$

$$j = \text{known} \qquad (10)$$

$$k = \text{known} \qquad (11)$$

$$\frac{h}{f+g} = x_2 = \text{known} \qquad (12)$$

In case of direct steaming, equation (12) holds good. For indirect steaming, `h' should be taken as zero.

We can see that all of the equations shown above are independent of each other, i.e. none of the equations written above can be derived by using other one or more equations (s). In this way, solving these equations yields in the value of each of the variables used. In this way, it is basically a macro-level material balance applied over the batch digester.

MODEL APPLICATIONS

The application of this model is two fold, of more importance, it allows the process engineer to analyze and cross check the process control parameters, such as active alkali, bath ratio etc, Another advantage is that the model is mainly dependent on the variables which can be measured preciously even in industrial units - volume of black liquor and white liquor can be measured accurately, their solid concentrations can be determined with significant accuracy, the pulp analysis for the moisture, fibre content etc. can be made accurately. The only part which may cause a little error is the moisture in the raw material, the reliability of which can be improved by proper sampling technique.

In the present system, we make use of the direct relationships-

$$\text{Yield} = \frac{\text{Oven dry pulp produced}}{\text{Oven dry weight of raw material}}$$

$$= \frac{\text{Volume of pulp X pulp consistency}}{\text{Digester volume X packing Density X Moisture}}$$

We know that the packing density of the raw material inside a digester is a complex function of moisture, packing etc. By using the above equation we make the yield values more sensitive to errors.

Furthermore, if the mill has only one blow tank, from which the pulp is continously taken away to further processing, it is even more difficult to determine the volume of the pulp produced in a particular cook. With this background, we can see that the yield determination is extremely difficult by using the conventional method.

EXPERIMENTAL PROCEDURE FOR THE DETERMINATION OF YIELD

For the analysis of the digester, the volume of black and white liquors are known initially. Their concentrations are also known using the first four equations, it is now possible to determine the values of a, b, c and d. The moisture in the chips can be taken by taking the representative samples from the raw material being fed to the digester.

Some amount of pulp is then taken after the pulping is over and just by means of squeezing it, the black liquor is separated, which is then analyzed for the solid concentration. By this way, we get the value of {J/(i+j)} X100 as percent solids concentration. Now another part of the pulp is dried and thus the value of {i/(i+j+k)}X100 can be obtained. (i+j+k) is the total sample weight. From this information, values of i, j and k can be obtained. It should be kept in mind that the values of i, j and k are not the absolute net values, but are the representative values for one Zth fraction of the pulp. Now, after solving the remaining equations, the values of all other variables can be obtained.

Once all of the variables have been obtained, the value of yield can be obtained by using the equation.

$$\text{Unbleached Pulp Yield, \%} = \frac{f}{f+g} \times 100$$

CONCLUSION

The proposed method employs no complicated mathematical procedure for solving the digester model. Neither the pulp volume or consistency, nor the weight of the raw material or packing density of the raw material is required for the determination of Yield. This method is specially useful for the raw materials which show a significant sensitivity of the packing density with change in moisture content, such as agri-residues.