Hydrapulper optimization by two dimensional sequential search

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ABSTRACT

The paper describes the application of the sequential search techniques for the optimization of hydrapulpers. The method has been discussed in detail for the help of readers who are not familiar with the optimization techniques, and their application to the pulp and paper industry.

Introduction :

The pulp and paper mills often have various equipments operating at the conditions much away from the optimum. This optimum value may be in terms of capicity utilization, quality requirements, energy efficiency etc. The optimization, whatever the nature of it may be, can easily be done for the equipments controlled only by one variable. This happy situation does not always occur in most of the processing systems. Search with more than one variable is very complicated primarily because-

1. There is lesser probability that the control variables exhibit unimodelity,
2- In most of the cases, the efficiency measurements may be extremely difficult.
3. The number of the experiments to collect the data and hence the computation required is very high.
4. In some cases, the effect of one variable is dependent on other variables.

Of course,sufficient amount of literature is available on direct search techniques with a single variable, no suitable method has been developed so far to solve the problems of multidimensional nature easily. Hence, it becomes the responsibility of the process engineer to develop and implement suitable search techniques for process optimization depending upon the requirements of specific problems.

Obviously, the simplest search plan could be to divide each of the variable into certain values, within the range,determine the output values at all of these process conditions and choose accordingly the optimum value out of these. This method though seems very simple contains some limitations. Say, for example, we have 5 variables, and we decide to take 5 observations for each value. Thus, the total number of experiments performed will be $5 \times 5 \times 5 \times 5 \times 5 = 3125$ experiments. Hence we need a method which gives us a direction to move towards the optimum thereby reducing the number of required experimentation.

Now, let us consider the case of a hydrapulper which is a good example of two-dimensional optimization problem.The problem reads like this—

Problem :

A mill has some number of hydrapulpers. Due to the mechanical trouble a few of them are out of operation and are not expected to be under operation soon. The production of paper is now wholly dependent upon the pulp produced by the hydrapulpers.

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Due to the technical limitations, except for the pulping time and waste paper charged, no other process variable is allowed to change. In addition to that, no straight formula is available which gives the production rate as a function of pulping time and charge. The company decides that the hydrapulper should be run at the highest possible production rate, even if it causes s slight increase in the energy consumption. Design a strategy for obtaining the maximum Production with the existing pulpers.

Solution :

For optimization we make certain assumption—

1. Between any two batches, Tl time is lost in charging and emptying of the pulpers. This time is independent of the amount of waste paper charged to the hydrapulpers.
2. The waste paper contains xr fraction of rejects.
3. The pulp produced contain xl fraction of lumps, which cannot be used for papermaking, and is returned back to the hydrapulper again.
4. At a time Q quantity of waste paper is charged.

Now, from the above, we may calculate the production rate—

$$P = \frac{Q * (1-xr) * (1-xl)}{Tl + Tp} * (24 * 60) \text{ Tons/day.}$$

Where, Tp is the time of pulping in minutes, and P is the Production per day.

From the above equation it is obvious that if pulping time per batch is low then the production rate will be high. But if the pulping time is very low then the disintegration of the fibers will not be adequate (i.e. xl will be high) which further reduces the production rate.

Figure 1 indicates a hypothetical nature of the production curves. In the figure, 0 is the point corresponding to the maximum production rate. In the figure, inner loops indicate a higher production than the outer ones.

For the purpose of obtaining conditions for maximum production we plot a graph between waste paper charge and pulping time, as shown in figure 2. Initially, we choose some values of the pulping time and waste paper charged and name as pivot point. We run the hydrapulper at the conditions in the neighbourhood of the pivot point. Some hypothetical values have been written in figure 2. Out of the four values, we select the optimum value (in this case, the maximum production) of the required property.

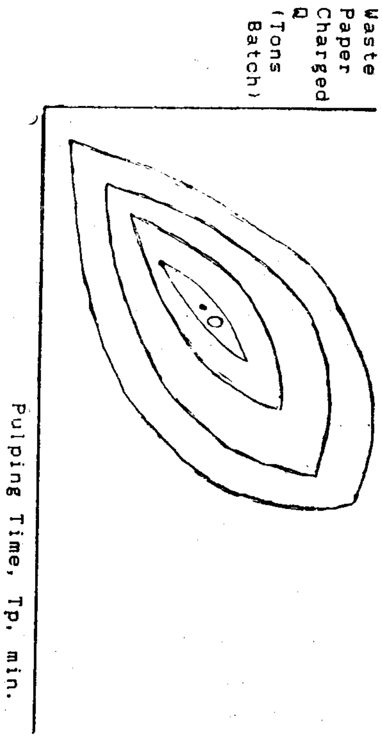

Fig. 1

Now, we designate the optimum point as the pivot point, and repeat the experiment around this point. Now, if the values obtained are lesser than the previously obtained values, then the optimum has been achieved. If it is not so, we keep on repeating the experiments. Normally, the optimum is expected to be obtained within two or three experiments; thus, we are required to run hydrapulper around 8-11 times.

For example, in figure 2 we, select point pl as the pivot point. Now, we can make experiments at four points indicated by the corners of rectangle A. Say, we obtain the maximum production at the right-top corner. Now, this becomes the pivot point and experiments at the corners of the rectangle B indicate the right-top corner is again the better one. In case of rectangle C, we see that there exists no point which

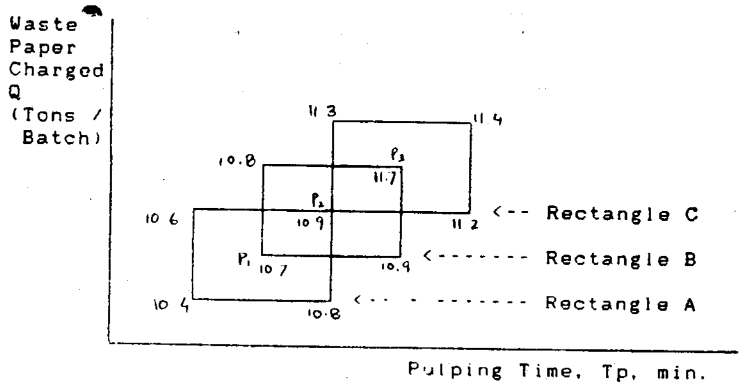

Fig. 2

gives more production than the previously obtained in rectangle B. Hence we may say that the right-top corner of the rectangle B is the optimum.

Conclusion :

The method has certain benefits. First of all, the method assures a maximum capacity utilization of equipments, which sometimes is not available due to continuosly changing process conditions. The another advantage is that to apply this method one does not required to be very sound in fundamental mathematics. This method can also be used for energy optimization for hydrapulpers. In that case, instead of computing the amount of pulp produced, the energy consumption per unit ton of pulp is to be determined, and the search should be made in the direction of the least energy consumption per ton of pulp.

Reference :

1. Rao, S.S., "Optimization : Theory and Applications", 2/e, Wiley Eastern Ltd., 1987, pp 219.