APPLICATION OF SIZE REDUCTION THEORIES TO DISC REFINER PULP PRODUCTION

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The disc refining process for mechanical pulp production is now a well established unit operation in the pulp and paper industry. Present trends indicate that in future it will play a major role in the production of sanitary tissue, newsprint, magazine paper, and higher grades of paper.

The disc refiner is a counterpart of the attrition mill which is used extensively by the comminution industries for a wide range of size reduction operations. Two types of refiner are available. The double disc refiner is equipped with two parallel steel discs which rotate in opposite directions, whereas in the single disc refiner one plate is stationary and the other rotates, giving a relative contra-rotation action. The wood chips are fed in at the centre of the discs where they are broken down by mechanical action and travel radially towards the periphery of the discs by centrifugal action. The discs which have radial, grooved patterns on their outer surfaces, defibre the fractured chips and reduce them to a high quality, long fibre pulp. Modern refiners commonly have 40in.-54in. diam. discs connected to 2,000hp-6,000hp drive units and they can produce 75-80 tons of pulp per unit per day.

Although the disc refiner occupies an increasingly important position in the industry, there is still no sound theoretical understanding of its operation. Traditionally the greatest research emphasis on refiner mechanical pulp production has centred around attempts to minimise power consumption and to improve pulp quality. This is quite understandable in view of the high energy inputs demanded by the first generation refiners. However, now that the design of disc refiners has become much more sophisticated, the power demand per ton of pulp has fallen considerably and this area could be expected to demand less research effort in the future. Although energy requirements will always remain an important parameter in the process any attempts to build up a theoretical model in terms of it would lack sufficient subtlety.

This same problem was faced by the comminution industry, and over the past two decades much theory has been developed to explain the nature of fracture and to describe the distribution of particle sizes in the reduced solid (Austin and Klimpel, 1964). Also, considerable work has been done on the effect of the attainable size distribution on the product. These theories have been used to improve existing grinding processes, and in order to test whether the same work could be applied to the disc refining process a series of pulps were prepared in a Sprout-Waldron laboratory refiner and the fibre classification data obtained. The results of this initial work have shown that the size distribution of fibres in a pulp sample can be described by a simplified version of the Rosin-Rammler function, R = 100 exp (–bx), where R is the percentage of fibres larger than size x (Corson, in prep.). When this function is plotted on log-normal graph paper for a specific pulp a straight line which passes through the point (0,100) is obtained and the position of the line is fixed by the gradient, b. Because the gradient is heavily dependent on the long fibre fraction which in turn is dependent on the chip feed size and the refining conditions it is feasible that it could be used as a parameter for mill control. Also, as this work showed that the distribution of pulp fibres could be described by an exponential law, it proved for the first time that a definite law governed the refining process.

As a result of this a further series of trials, based on Epstein's pioneer work on the size reduction of coal, were carried out. He proposed that a size reduction process could be described by two probabilistic functions. The first, the rate function, S(x), is the probability that a particle of size x will be broken down. The second, the breakage function, B(y, x), is the probability that particles that were originally of size x will be broken down to size y or less. So where H(y) is the size distribution of

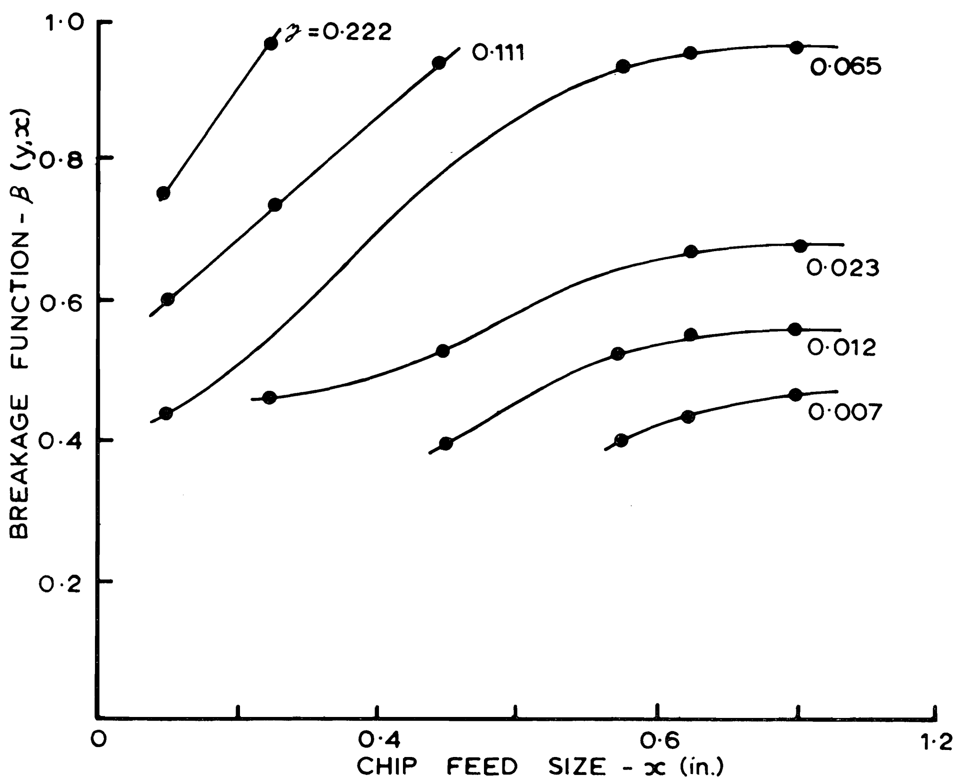

FIG. 1—Experimentally determined breakage functions for constant values of the reduction ratio z (= y/x). Note: "0.6" on the abscissa should read "0.8".

particles which pass through a grinding mill unbroken, the product size distribution, G(y), resulting from a steady state continuous process is given by the integro-differential equation

$$G(y) = H(y) + \int_{y}^{\infty} S(x)B(y,x)\, dH(x)$$

As all wood chips are broken down to individual fibres or fibre bundles in a disc refiner, the rate function for the overall process is equal to unity; so only the breakage function was investigated in the initial trials. Curves of breakage function vs chip feed size, x, have been plotted in Fig. 1. It can be seen that these conform to a general pattern which corresponds to those obtained by other workers for coal and mineral ores. Although no attempt has been made to calculate the breakage functions because of the lack of suitable computational techniques, it is significant that the experimental results relate to the theory. It should be noted that since this work was completed a number of papers have been published on the calculation of breakage functions and it is expected to apply these to the data in the next stage of the project.

In conclusion, it has been shown for the first time that general comminution theories can be used to describe the breakdown of wood chips in a disc refiner. This breakthrough will open up an entirely new field of pulp mill simulation and closed circuit optimisation. In turn, this will lead to a better understanding of the disc refining process and enable the production of pulp of more uniform quality at a lower price. Also, as the physical properties of paper are related to their fibre size distribution, it will be possible to control more strictly the operations in a refiner mill to produce pulp of the desired quality.

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CORSON, S. R. (in prep.): Fibre distribution theory of disc refining.