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WHAT'S NEW IN FOREST RESEARCH

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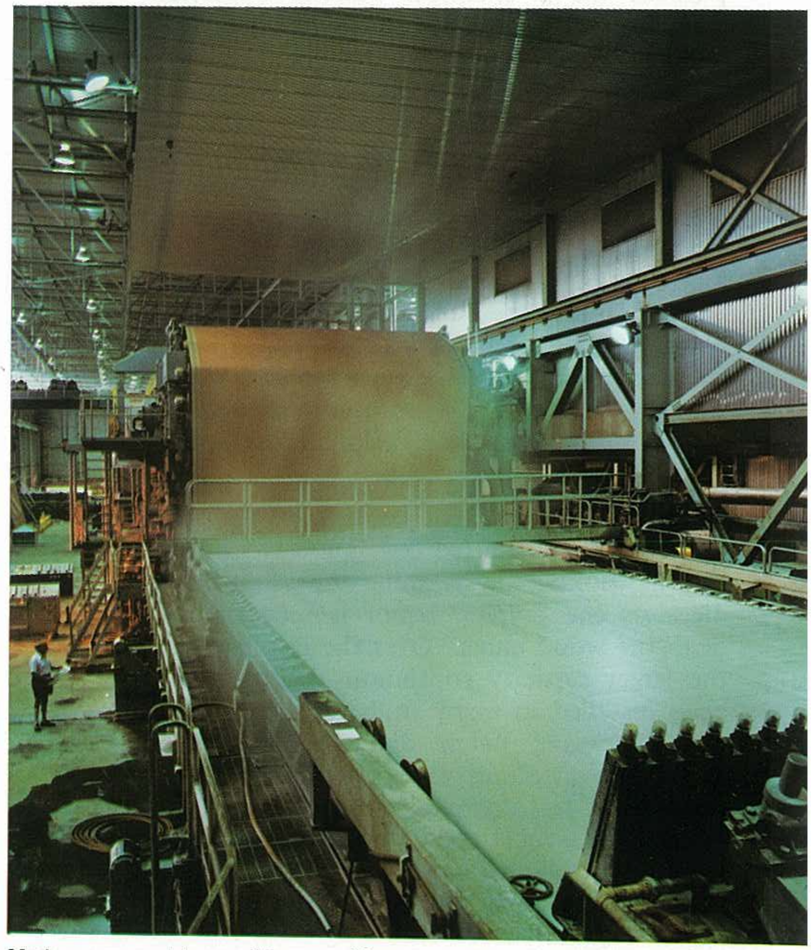
Development and Use of a Mathematical Model for Kraft Pulping

Like all developed countries, New Zealand uses large quantities of paper and cardboard. Writing paper, wrapping paper, tissue paper, wallpaper, newsprint, books, cartons, paper dishes are just a few of the hundreds of items made from paper. Furthermore, the amount we use is increasing each year. For the year 1921, our consumption was 15 kilogrammes per head of population; by 1974 it had climbed to 148 kilogrammes. Happily for our economy, not only is most of our paper and cardboard, and the pulp from which it is made, manufactured in New Zealand, but we also export considerable quantities. For example, in 1973 (provisional figures) we exported 141 521 tonnes of pulp and 148 018 tonnes of newsprint and other paper, and paperboard. This brought us overseas earnings of $35 156 000. Clearly the manufacture of pulp and paper is one of our important industries.

A large proportion of our pulp is manufactured by the kraft pulping process. It is a large-scale operation using energy and chemicals to convert wood chips into pulp. Wood, however, is an extremely variable raw material, and this makes precise control of the operation very difficult. It is essential for the industry to be able to produce pulp of consistent



Modern papermaking machines need large quantities of good quality pulp. At the "wet end" the dilute pulp is deposited on a fine mesh wire and as the wire moves along at high speed (from right to left) the water is sucked out leaving a mat of pulp. After being pressed between felts the pulp is dried to form a continuous sheet of paper. (FRI CN5216).

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quality so, because of the problems involved and because of the importance of kraft pulping to the New Zealand economy, scientists in the Pulp and Paper Section of FRI some time ago began studies of the process. They have now developed a mathematical model of kraft pulping, and have used the model to devise suitable control methods for the operation.

What is kraft pulping?

Wood is a complex, heterogeneous material composed of many long, narrow, tubular cells often referred to collectively as fibres. The three major chemical constituents are cellulose, hemicellulose, and lignin. Lignin cements the fibres together, and the main purpose of a chemical pulping operation such as kraft is to dissolve the lignin so that the fibres can be separated easily from each other. Much of the hemicellulose is dissolved with the lignin, but almost all the cellulose, which gives the fibres their strength, is retained. So, kraft pulp fibres are characteristically strong, and when bonded together again form a very strong sheet of paper. Kraft pulping, which was invented by the German chemist Dahl, in 1889, involves cooking wood chips in a digester at a maximum temperature of between 165 and 180°C for 2-4 hours, in a solution of sodium hydroxide and sodium sulphide in water.

Pulping is carried out in either continuous or batch digesters. In continuous digesters the wood chips are fed continuously through various cooking and washing zones; in batch digesters the pulping liquor is recycled through the wood chips. Over the last 10 years the larger capacity continuous digesters have been installed in many mills, but some mills are still using batch digesters. Possibly because controlling the process in batch digesters is less complex than in continuous digesters, the most recent trend appears to be towards installing batch digesters again. FRI studies have so far been restricted to batch digester operation.

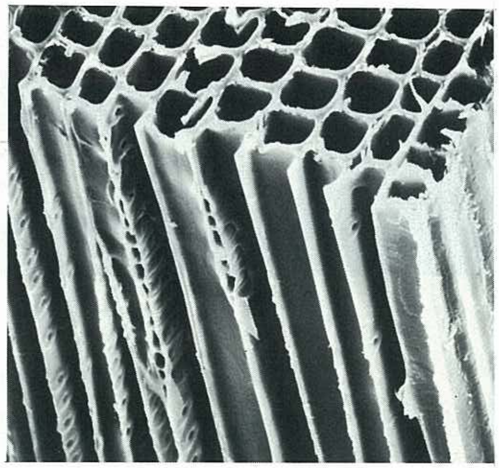
Kraft pulping control

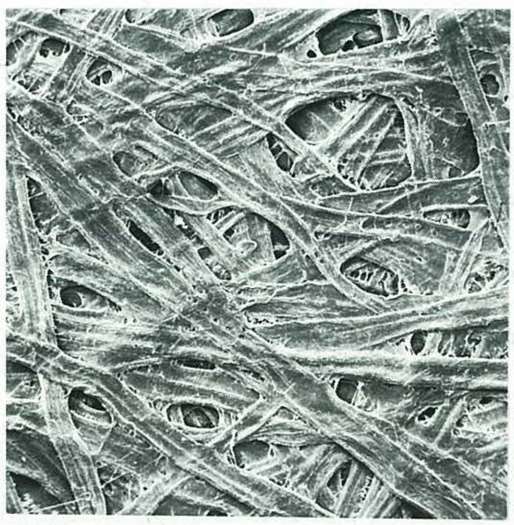
Although removal of most of the lignin is the objective of kraft pulping, some remains in the pulp after cooking. Variations in the amount remaining affect other mill operat-

From top, block of radiata pine wood X100. (FRI BW71/7)

Kraft pulp fibres produced from the wood X100. (FRI BW943/7)

The fibres bonded together to form a sheet of paper X100. (FRI BW240/16)

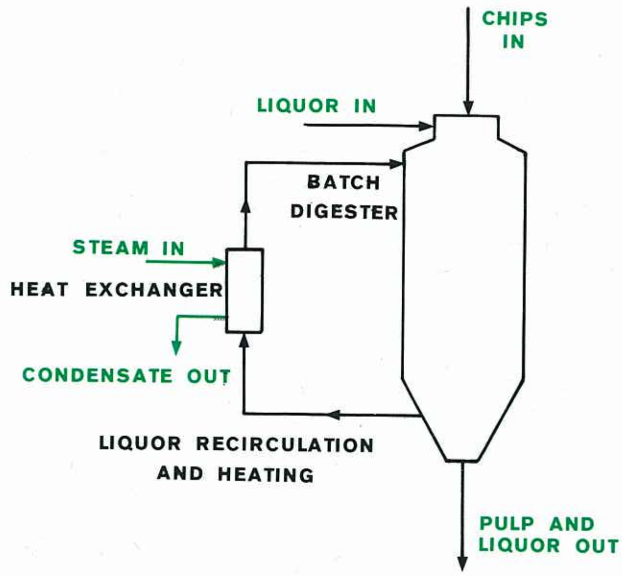




ions such as bleaching and papermaking, and also the final properties of the paper. Therefore, it is important to control the pulping operation so that the amount of residual lignin is always at a constant specified level.

The lignin content of the pulp depends on many factors such as the species, size, and moisture content of the wood chips, the composition of the liquor in which the chips are cooked, and the time/temperature schedule. Control of the lignin content is obtained by varying some of these factors, notably the alkali content of the initial cooking liquor and the cooking schedule. This is done manually at present and operator experience is relied on to a large extent. Unfortunately, because of the variability of wood, this approach has limitations and the industry has shown interest in the possibility of using a computer to achieve more precise control.

Before a computer can be used it is necessary to know how the lignin content of the pulp depends on the other factors. This information is obtained by studying the pulping operation in laboratory experiments, and is then expressed in a set of equations known as a mathematical model which can be used to program the computer.



Flow diagram showing the operation of a batch digester.

Developing the model

Kraft pulping experiments were carried out at FRI in laboratory digesters using wood chips of radiata pine and cooking conditions similar to those used in industry. The cooking was done at three different maximum temperatures with five initial cooking liquors,

Sample of pulp liquor being taken from the laboratory batch digester during FRI experiments. (FRI CT119).

each with a different alkali content. For every combination of these conditions samples of the chips were cooked for varying lengths of time. At the end of each experiment the pulp was analysed for lignin content, and the residual liquor for alkali content. This enabled scientists to follow the way in which both the lignin content of the pulp, and the alkali content of the liquor, decreased during cooking.

A constant mathematical relationship was found to exist between the alkali content of the liquor and the lignin content of the pulp. This relationship was combined mathematically with a known kraft pulping rate equation to yield the basic form of a practical mathematical model relating the lignin content of the final pulp to the more important of the pulping factors mentioned earlier. The H-factor, a single variable that takes account of the effects of both time and temperature on the pulping, was also incorporated in the model. This is important as the H-factor can be monitored continuously throughout a kraft cook and can be used for control purposes in place of time and temperature. The effects of deviations from a specified time-temperature schedule can therefore be overcome simply by cooking to the required H-factor.

The model has now been extended to include the effects of the remaining factors such as size and moisture content of the chips. It has been proved applicable to kraft pulping in industrial batch digesters, and recent laboratory experiments indicate that it is applicable to the pulping of New Zealand beech as well as radiata pine.

Using the model

If the initial conditions in the digester are known, the model can be used to predict the H-factor required to produce pulp of a specified lignin content. However, in industry precise measurement of some of the initial conditions poses a problem. The size, moisture content, and wood quality of the chips vary considerably from batch to batch, and are difficult to measure in practice. Because of this, FRI scientists used the model to develop a control method which eliminates the need for such measurements. The only analysis required is that of the alkali content of a small number of liquor samples taken from the digester at known H-factors soon after the start of pulping. The method is suitable for either manual or computer control and would be used to indicate to the operator of the digester the H-factor at which to stop cooking so that pulp of the desired quality is obtained.

The future

Tests of the control method on industrial batch digesters have just been successfully completed and the method can now be put to practical use by the pulp and paper industry. The expected improvement in pulp uniformity will have many advantages including increases in the amount of pulp obtained from the wood, and decreases in the consumption of chemicals used in bleaching. It will also enable the bleaching and papermaking operations to be controlled more effectively. It is envisaged that the control method could finally become the basis of a comprehensive computerised batch digester control system for the complete cooking operation.

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