

SOME DIFFERENCES IN THE BEATING BEHAVIOUR
OF SOFTWOOD AND HARDWOOD PULPS

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ABSTRACT

Certain differences in the beating behaviour of softwood and hardwood pulps, more specifically pine and birch kraft pulps, are discussed. Due to large differences in dimensions and structural properties of the fibres, the physical properties of the pulps develop quite differently, depending on the beating conditions. In most cases, hardwood pulps require gentler beating conditions than softwood pulps. The bar clearance in the refiner when refining birch is only about half of that when refining pine. Due to the differences in optimum beating conditions, separate beating of hardwood and softwood pulps is preferable in most cases.

INTRODUCTION

The chemical pulping process was originally developed with softwood as the raw material. It was not until late 50s and early 60s that the pulping industry started using hardwood as a raw material on a large scale. Since then the amount of hardwood used for pulping has increased continuously and will continue to do so due to the large amounts of hardwood available in tropical and subtropical regions.

Because the morphology of softwood and hardwood fibres is quite different, they may be expected to behave quite differently on beating. Over the years the Finnish Pulp and Paper Research Institute has carried out beating experiments on both softwood and hardwood pulps. There seem to be certain systematic differences in the beating behaviour of softwood and hardwood pulps, and the aim of this paper is to briefly discuss the main differences observed.

STRUCTURAL PROPERTIES OF SOFTWOOD
AND HARDWOOD FIBRES

Before going into a discussion of the beating behaviour of different types of pulp it may be worthwhile to recall their structural properties. For this reason certain dimensions and other properties of a few softwood and hardwood species are shown in Tables 1 and 2¹. A look at these figures immediately reveals the following differences:

- Hardwood fibres are much shorter and narrower than softwood fibres.
- Hardwood fibres generally have a higher relative cell wall thickness than do spruce/softwood fibres. This means that hardwood fibres are stiffer and have a greater resistance to collapse than most softwood fibres.
- Hardwood pulps always contain a large amount of thin-wall vessels.

- On the softwood side, there is a distinct difference between springwood and summerwood fibres. This difference is much smaller in the case of hardwood fibres.
- Hardwood fibres are short and therefore have a much smaller rotational volume than softwood fibers and thus a much smaller flocculation tendency.
- The number of hardwood fibres per unit mass is always much larger than that of softwood fibres.

In summary, this means that when beating hardwood fibres we are dealing with a much larger number of smaller, stiffer, less collapsible and less flocculating fibres than when refining softwood fibres.

In addition to these physical differences, there are also certain differences in the chemical compositions of softwood and hardwood fibres. The main hemicellulose of hardwood is xylane, whereas the main hemicellulose of softwood is glucumannane.

The variation between different species in respect of properties is larger among hardwoods than among softwoods. Thus it may be more dangerous to generalize when drawing conclusions concerning hardwoods than it is in the case of softwoods.

In the Scandinavian pulp and paper industry the most important hardwood is birch (*Betula* sp.), while spruce (*Picea abies*) and pine (*Pinus silvestris*) are the important softwood species. In the following the discussion will concentrate on bleached kraft pulps from birch and pine, respectively. The reason for this is simply that most of our experience is based on beating these pulps. When drawing conclusions from beating these pulps, it should be borne in mind that birch and pine are among the most suitable hardwood and softwood species for pulping and papermaking purposes.

EXPERIMENTAL

The results discussed in the following were obtained from several studies of the beating response of different types of fibres to different methods of beating. Laboratory beatings were carried out in standard Valley and PFI beaters, and in an Escher-Wyss conical refiner at different specific edge loads. A large number of physical measurements were made on the beaten furnish as well as on handsheets made from it. In one study, the beaten fibres were also dried according to the critical point drying technique⁴ and microphotographs of the dried fibres were taken with a Scanning electron

microscope. The aim of this was to try to correlate visible changes in the fibre structure with changes in the physical properties of the pulp and of the laboratory sheets.

REACTION OF BIRCH AND PINE PULPS TO BEATING

DEVELOPMENT OF FIBRE PROPERTIES ON BEATING

SEM-micrographs of the beaten fibres indicate that the external fibrillation of birch fibres is less pronounced than for pine kraft fibres. The range of visible changes in the fibre structure seems to be smaller for birch fibres than for pine fibres. This can be seen from Figs. 1 - 2 (see foll. pages), which show birch and pine fibres at different stages of beating. These differences in external fibrillation are probably due to differences in the fibre structure. The hardwood fibrils emanating from the fibres are probably smaller and thinner than in case of softwood². This may be expected to cause differences in fibre bonding ability. Measurement of strength properties indicates that the bonding ability of birch fibres develops somewhat more slowly on beating than that of pine fibres.

It has also been observed in the case of birch fibres that there is a severe reduction in fibre length during refining at lower specific edge loads than in the case of pine kraft fibres. This can be seen from Fig. 3, in which the reduction of the average fibre length is plotted as a function of the pure specific beating energy applied at different specific edge loads. The average fibre length was calculated from Bauer-McNett classifications of the beaten pulps.

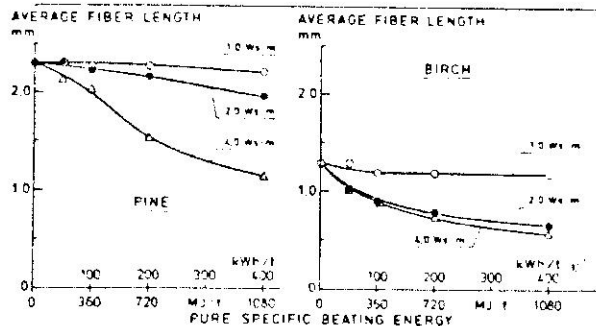


Fig. 3. Average fibre length vs pure specific beating energy for bleached pine and birch kraft pulps.

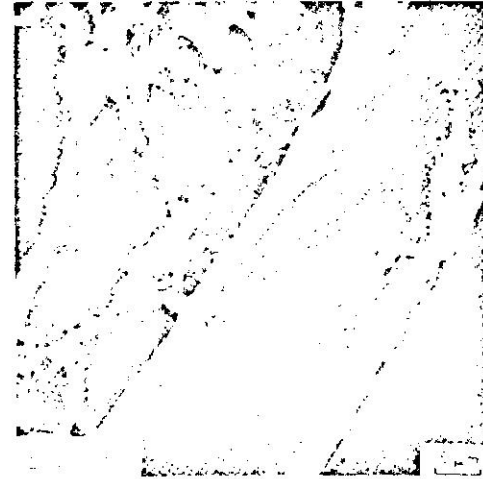


Fig. 1. Bleached pine kraft pulp beaten in the Escher-Wyss conical refiner at a specific edge load of 1 Ws/m.

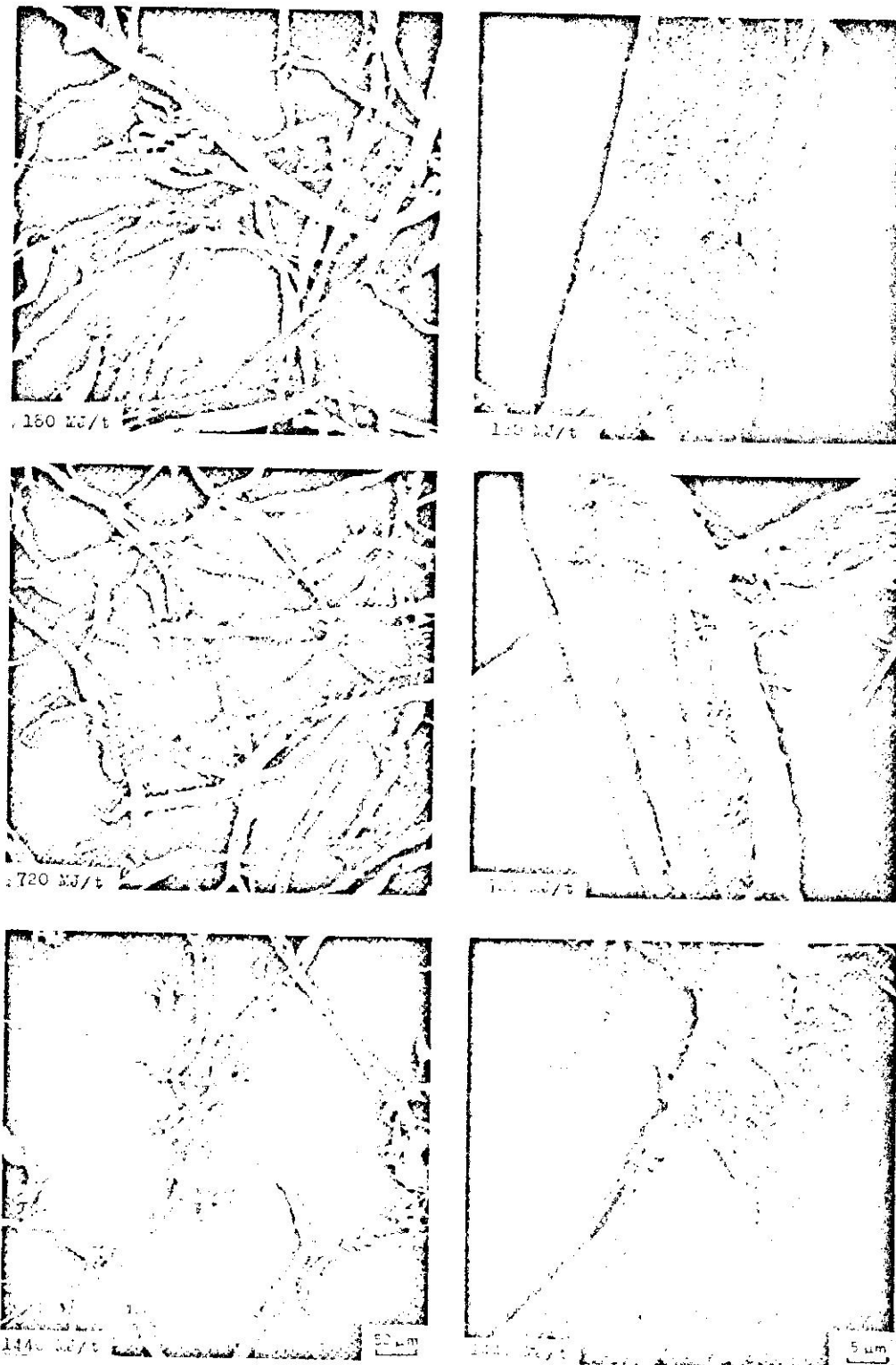


Fig. 2. Bleached birch kraft pulp beaten in the Escher-Wyss conical refiner at a specific edge load of 1 Ws/m.

The curves indicate that at a low specific edge load of 1,0 Ws/m there is no reduction in the fibre length in either of the pulps. At a high specific edge load of 4,0 Ws/m the fibre length in both pulps is reduced quickly and at the same rate. At a medium specific edge load of 2,0 Ws/m the birch fibre length is reduced fairly rapidly as a function of the beating energy, whereas pine fibres retain their length much longer. This also influences the development of the physical properties of laboratory sheets made from the pulps.

DEVELOPMENT OF PAPERMAKING PROPERTIES AS A FUNCTION OF BEATING CONDITIONS

In the following the development of the papermaking properties of birch and pine kraft pulps are compared on the basis of beatings carried out in an Escher-Wyss conical refiner at different beating intensities (specific edge loads) and amount of beating (pure specific energy consumption).

The SR number is plotted against the pure specific beating energy consumption at low and high specific edge loads for the two pulps concerned in Fig. 4 and tensile strength in Fig. 5. The figures indicate that for both pulps the effect of beating intensity, i.e. the specific edge load, on the development of these properties is quite considerable. The interesting point in Figs. 4 and 5 is, however, that the SR number and tensile strength of birch pulp increases more quickly at a low specific edge load than at

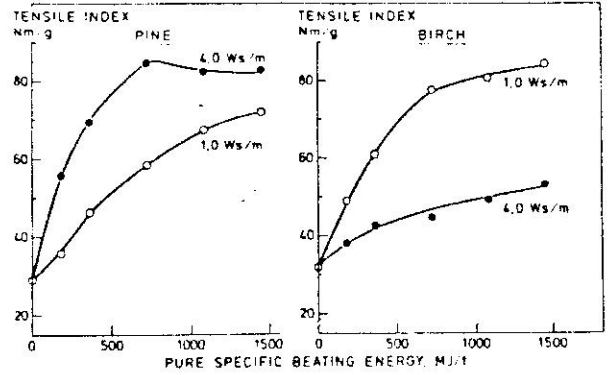


Fig.5. Tensile index vs pure specific beating energy for bleached pine and birch kraft pulps.

a high one. For pine the situation is the opposite, i.e. the more intense the beating, the quicker the increase in SR number and tensile strength. This means that to generate a high tensile strength rapidly, birch fibres require a gentle beating while pine requires a harsh beating.

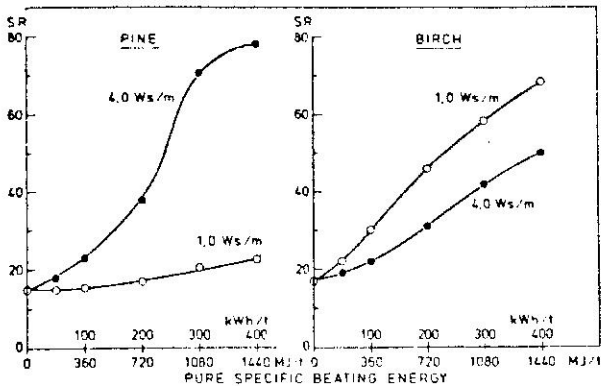


Fig.4. SR vs pure specific beating energy for bleached pine and birch kraft pulps.

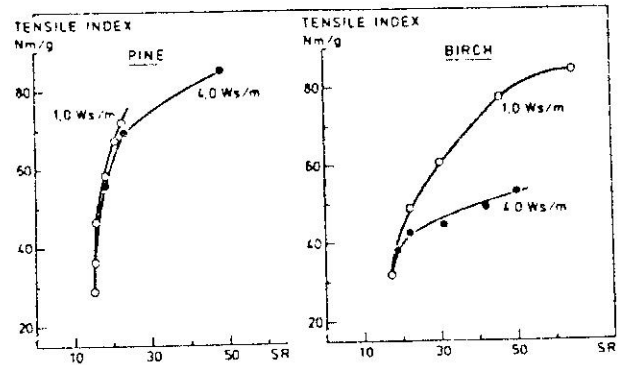


Fig.6. Tensile vs SR for bleached pine and birch kraft pulps.

A plot of tensile strength against SR at different specific edge loads yields similar curves for both pulps (Fig. 6).

The reason for the somewhat strange behaviour of birch fibres described above is not yet fully understood. A pseudo-explanation is offered by

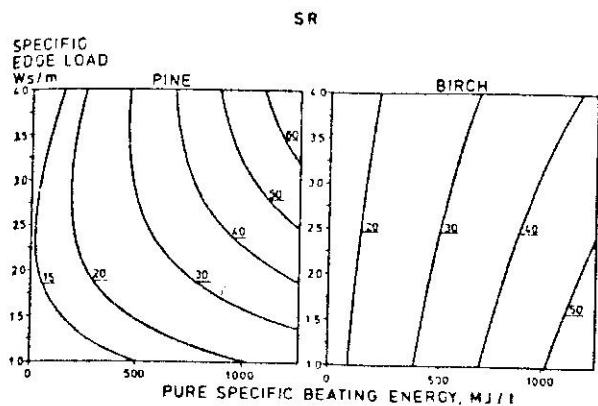


Fig.7. Equi-level curves for SR for bleached pine and birch kraft pulps.

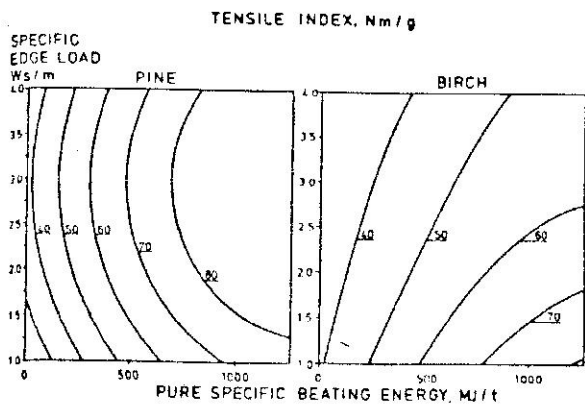


Fig.8. Equi-level curves for tensile index for bleached pine and birch kraft pulps.

Fig. 7, which shows the equilevel curves for SR of pine and birch plotted in a diagram with the control variables of the beating, i.e. the specific edge load and the beating energy consumption on the axes. Fig. 8 shows the same thing for tensile. These figures support the earlier findings that the SR and tensile strength for birch develop more quickly the lower the specific edge load. This also means that the energy applied to a hardwood pulp should take the form of a large number of gentle hits rather than just a few hard ones.

A more likely explanation for the different behaviour of birch and pine fibres on beating may lie in the larger number and lower flocculation ability of the former compared to the latter. This would mean that in the case of birch, a much smaller proportion of the fibres present in the furnish is flocculated and entangled in the fibre pad formed on the leading edge of the rotor bar. Thus the number of fibres remaining in the grooves and thus receiving no treatment at a given moment is much larger in the case of birch than for pine. Decreasing the load means an increase in the bar clearance. This may increase the size of flocks and thus the amount of the fibres receiving treatment. For each type of pulp an optimum bar clearance probably exists at which hits of optimum energy hits are distributed among fibres in optimum sized flocks. This optimum bar clearance seems to be quite different for birch and pine pulps.

Another distinct difference between birch and pine kraft pulps is the development of tear

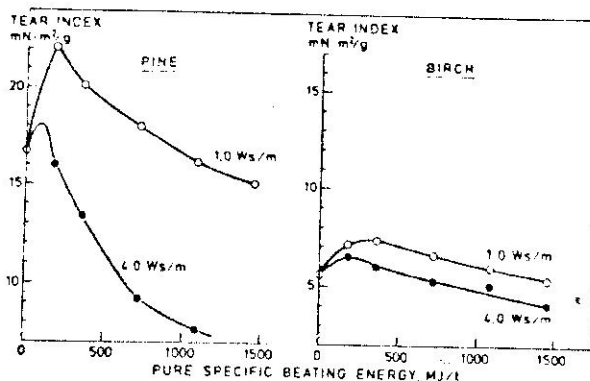


Fig.9. Tear vs pure specific beating energy for bleached pine and birch kraft pulps.

strength as a function of beating energy consumption. This is plotted in Fig. 9 for the two pulps at different specific edge loads.

The large difference in tearing strength between the two types of pulp is due to the difference in fibre length. The development of tearing strength as a function of beating energy would, however, indicate differences in the development of fibre bonding ability on beating. Pine kraft fibres typically reach a sharp maximum in tearing strength after only a small amount of beating or at low levels of tensile strength, whereas the tearing strength of birch and other hardwood pulps increases much more slowly and reaches a much wider maximum at a higher tensile strength than for pine fibres (Fig. 10). This corresponds with the observations on external fibrillation mentioned above.

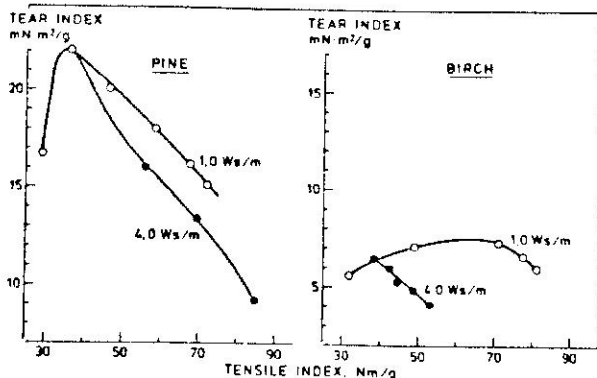


Fig.10. Tear vs tensile index for bleached pine and birch kraft pulps.

For both types of pulp a harsher beating reduces the tearing strength in relation to tensile strength more rapidly than a gentle type of beating. This effect is, however, more pronounced for birch pulp (Fig. 10) than for pine and corresponds with the results on fibre length discussed above. In relation to the beating energy applied, the tearing strength of pine kraft is, however, more sensitive to the beating intensity than the birch kraft (Fig. 9).

When comparing different hardwood pulps it can be observed that the lower and slower the general strength development of the pulp is, the wider is the tear maximum. At the same time

the amount of beating energy required to reach this maximum increases (Fig. 11). Thus the shape and position of the tearing strength curve may be seen as a reflection of the fibres' bonding ability, which is in turn a function of the external and internal fibrillation of the fibres on beating.

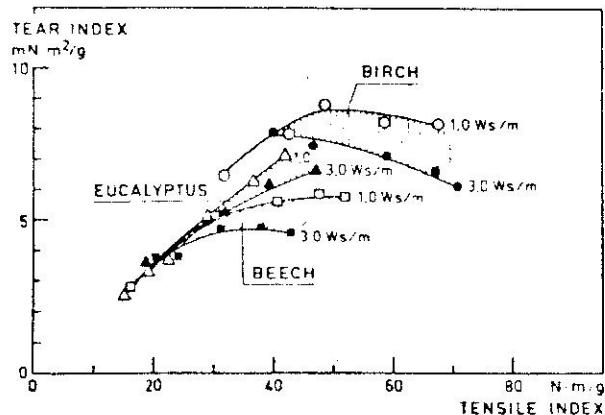


Fig.11. Tear vs tensile for different hardwood kraft pulps.

In terms of other papermaking properties birch and pine fibres react similarly to beating. Thus the light scattering coefficient as a function of tensile strength remains higher, the lower the specific edge load during beating. Air resistance v tensile strength also increases at a higher rate, the harsher the beating. These features are common to both softwood and hardwood kraft pulps.

The results discussed above indicate that the optimum beating conditions for softwood and hardwood pulps are generally quite different. In the case of softwood kraft pulps, strength properties are normally the most important and these properties develop in the most economical way at rather high beating intensities, i.e. high specific edge loads. In the case of hardwood kraft pulps, the tearing strength is often a drawback; but also the light scattering coefficient of the pulp should also remain high. For these reasons, hardwood pulp requires a very gentle type of beating, which is quite different from that which is optimum for pine.

CONDITIONS PREVAILING IN THE REFINER

The conditions prevailing in the refiner during beating are discussed extensively in Dr. Nordman's paper⁵, which deals with both softwood and hardwood pulps. In this connection only one of the interesting features will be briefly discussed.

The biggest difference between the refining conditions for birch and pine fibres is the bar clearance. When refining birch pulp, the clearance is only half or even less than when refining pine fibres. To a certain extent this may be explained by the differences in fibre diameters and cell wall thickness. Another explanation, however, seems to be that the greater flocculation ability of pine fibres creates larger flocks between the bars when refining pine than when refining birch. In practice this means that by increasing the load it is much easier to get metallic contact between the rotor and stator bars when refining birch than when refining pine.

MIXED V SEPARATE BEATING OF BIRCH AND PINE

Very frequently paper is made from a mixture of hardwood and softwood fibres. This is particularly true of the large group of "wood-free" printing and writing papers. In these, hardwood pulps is the main component and softwood pulp is used merely to give the furnish sufficient strength. The question frequently raised is: should the hardwood and softwood fibres be beaten separately or after mixing?

Since the optimum beating conditions for birch and pine fibres are in most cases quite different, the logical answer to this question is to beat the furnish components separately. This has also been found in experiments with mixed and separate beatings carried out at the Finnish Pulp and Paper Research Institute. This establishes the refining of each component to be separately optimized. Separate beating also seems to give the beating system a much larger flexibility and thus larger scope for obtaining certain end properties.

Separate beating of the components always means higher investment costs and a more complex refining system. The relevant question is often: are the benefits provided by separate beating large enough to justify the higher investment costs?

No general answer can be given to this question; each case has to be dealt with separately.

Because there is normally a price difference between softwood and hardwood pulps, there often is an economical reason for maximizing the amount of hardwood pulp in the furnish. Depending on the case and on the properties required of the furnish, the maximum amount of hardwood pulp achievable may depend significantly on the choice of separate or mixed refining.

In order to get a basis for optimization of the amount of birch pulp in mixtures with pine, the Finnish Pulp and Paper Research Institute has carried out laboratory-scale model experiments using widely differing values for the variables mixing ratio, specific edge load and beating energy given to the mixtures and/or to the components. Regression equations between different papermaking properties and these variables have been established. These can now be used to find the low consistency beating conditions at which a maximum amount of birch pulp can be added to the furnish without decreasing any important papermaking property below certain specified limits. Full-scale tests indicate that the reference system formed by these regression equations works rather well. At the same time these experiments indicated that from the point of view of papermaking properties and maximization of birch pulp, a separate beating of the components is preferable in most cases.

It may sometimes be observed that the pine fibres, being thicker than the birch fibres, tend to protect these from receiving a harsh treatment in the refiner. What this actually means is that the birch fibres are beaten with a lower specific edge load and the pine fibres with a higher one than that applied to the furnish on average. This may give a beneficial effect in the development of certain strength properties of birch pulp, such as initial wet web strength and tearing strength. However, in most cases this is of minor practical importance. The main effect of mixing pine fibres into the furnish is the general increase in the strength properties due to the pine fibres themselves.

FINAL REMARKS

Some observations on differences in the beating behaviour of hardwood and softwood pulps, more specifically birch and pine kraft pulps, have been discussed above. The differences observed may generally be explained by differences in the dimensions and structure of hardwood and softwood fibres. Knowing these differences and understanding the reasons behind them will help us in predicting the behaviour of new fibres coming into use and also in calculating suitable furnish compositions for different types of paper.

As the reasons for the differences in beating, and more generally in the papermaking behaviour, of hardwood fibres are to be found in the fibres themselves, there is little the papermaker can do to eliminate them. A much more fruitful approach is to combine the fibre properties and thus to prepare furnishes with papermaking properties which would not be achievable with either type of fibres alone.

REFERENCES

1. -
Information compiled at the Finnish Pulp and Paper Research Institute.
2. Marton, R. - McGovern, S.O.:
Relation of Crystallite Dimensions and Fibrillar Orientation to Fiber Properties.
3. Levlin, J-E.:
On the characterization of papermaking pulps.
TAPPI 58(1975):1, 75-77.
4. Parham, R.A.:
Critical Point Drying for Fiber Microscopy.
TAPPI 58(1975):3, 138-140.
5. Nordman, L - Levlin, J-E. - Jokisalo, H. - Makkonen, T.:
Conditions in a LC-refiner as Observed by Physical Measurements.
Paper given at the International Symposium of Fundamental Concepts of Refining.
Institute of Paper Chemistry, Appleton, September 16-18, 1980.

