Optimisation Of Paper Mill Refining Systems

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INTRODUCTION

Refining is the most influential of all of the papermaking processes. The old adage that 'Paper is made in the beater (now refiner)' holds true for every paper product.

In relation to the other processes involved in papermaking, only drying uses more energy. Using 1993 Jala, UK production was 5.2 million tonnes, made on 153 paper machines. For those grades requiring significant amounts of energy for the refining of chemical pulps (~ 2.5 million tonnes) this energy is approximately 500000 megawatts at a purchase cost of Σ18 million. Although approximate the cost involved gives an idea of the potential for saving.

Although there are new refiners on the market which offer potential for energy saving, albeit at a penalty in capital investment, there are many ways in which energy savings can be made by means of good practice, eg maintenance, correct capacity and filling design.

However these opportunities are not always recognised and in many cases new systems are installed where, by changing operating practices and paying attention to the condition of equipment, similar savings in energy could have been made at much lower capital cost.

The purpose of this paper is to bring attention the potential for system modification to existing equipment and layout with some suggestions as to the course to follow when installing new refiners.

The practices described in this guide are for refining of virgin chemical fibre. Energy use in the production of mechanical pulps is a topic in its own right.

BACKGROUND TO REFINING

The practice of refining

Primary effects of refining

It is not proposed to go into great detail on the fundamental aspects of the refining process. The current knowledge with respect to the fundamental changes in the fibre during beating of refining has been reviewed by a number of researchers and a brief summary is given below.

The primary effects of refining, are:

- fibre cutting of shortening, measured optically or by increase in weight of short fibre fraction.
- fines production and the complete removal of parts of the fibre wall, creating debris in suspension.
- external fibrillation, the partial removal of the fibre wall, leaving it still attached to the fibre.

The papermaker must define the fibre modifications required for his process and product. The next stage is to achieve the desired effect via refining and its control. Conventionally, cutting and fibrillation are the desired effects of refining and the correct balance of these properties has the most effect on the energy used to produce a given product.

Refiner theory

Until recently refining was more an art than a science with the process qualitatively measured by reference to time or wetness development. Power

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was measured very occasionally but there was little reference to energy used.

This changed with the advent of formulae which described the refining process in a quantitative way and allowed the measurement of fibre treatment in terms of power and energy.

There are several theories which describe the severity and number of impacts received by a fibre the simplest to use is specific edge load (SEL).

Severity is the most easily measured by the specific edge load, while the number of impacts can be related to the specific net energy used in refining. The two equations best describing the refining process are thus:

$B_s = P_n / (L_s)$ (1)

$We = Pn/_m$ (2)

Where:

B_s = Specific edge load (Ws/m)

P_n = net power (kW) ie operating less backed off (no load) power

L_s = cutting edge "length" (km/s) obtainable from the refining manufacturer

W_e = Specific net energy (kWh/te)

m = dry fibre flow (te/h)

These formulae are not exact mathematical expressions but are used to visualise and quantify the refining process and are particularly useful for comparitive operational alternatives.

A high SEL, B_s, denotes a tendency to cut whereas a low SEL gives fibrillation. Using this theory a clearer picture emerges as to how to treat different fibres. A tough softwood fibre will require a high SEL whereas a relatively weaker hardwood fibre will require a much lower SEL.

From equations (1) and (2) it can be seen that the definition of SEL and specific energy depends particularly on the following refiner and stock parameters:

- refiner power (kW)
- no load power (kW)
- type of refiner tackle (for L_s) ie pattern, angle, bar length and width of the fillings
- rotation speed (for L_s)
- consistency of stock (for m)
- volumetric flow (for m).

The number and length of bars in a set of refiner tackle will determine the ability of that tackle to cut or fibrillate in an efficient manner Bar width, apart from affecting the number of bars which a refiner filling can have, is also thought by some to define a further refining attribute, the specific surface load which divides B_s by a bar width factor.

Application to paper grades and furnishes

In order to apply the specific edge load theory to the production of various grades of paper attention must be paid to their needs. Unfortunately, in many cases needs are diverse and contradictory, Some examples are as follows:

- Security papers require short, cut fibres in order to give good watermaking while needing longer, fibrillated fibres to give the strength and handle needed for such a high quality paper.
- coating papers need high strength from relatively highly refined, fibrillated fibres to give runnability in the coaters, but demands of dimensional stability require a moderate degree of fibrillation to reduce shrinking on contact with aqueous coating mixes.
- glassines and tracings need the water holdout and translucency which come from highly fibrillated fibres but also require high tear given by stock with little refining and long fibre length.

Whatever the product requirements the desired properties can be imparted by furnish selection and correct refining. The science of refining is to ensure that this is done with the right equipment under the right conditions. Only then will energy use be optimised.

Energy use by grade

Refining energy usage varies by product with filter and blotting papers requiring least energy and tracing paper requiring the highest input. Some typical powers are shown in **Table-1.**

Table-1

Typical Energy Usage by product

	Net Energy* (kWh/te)	Gross energy** (kWh/te)
Printings and Writings	60-100	90-300
Coating Papers	100-150	175-350
Carbonless Papers	150-200	250-500
Glassine/Greaseproof	450-600	600-1000
Tracing	800-1200	1600-3000

*Net energy is derived from the gross minus the no load power which is the power that is taken up by mechanical drag and turbulent forces and is therefore not available to treat the fibres.

**this figure depends on the refiner efficiency.

The potential for energy saving will be high in many cases, Methods of saving energy vary in complexity and capital intensiveness. For example, Many refiners are incorrectly sized or not well maintained and this results in a high no load power which reduces refiner efficiency.

Main types of paper mill refiner

One of the more sensible statements about refiner installation is the following: 'It should be noted that, within certain limits, when a refiner is properly applied, there is not a great difference between conical and disc refiners regarding their ability to develop fibres. In other words, a fibre cannot read the lable on the refiner and does not know if it is in a disc or a conical refiner. It is aware of only two things-how many times it is hit and how hard it is hit each time'.

Choice of refiner must be to give the correct treatment needed for the product to be made. Only when this primary consideration has been taken into account should the other, nonetheless important, consideration such as reliability, efficiency, etc be taken into account. This section describes the main varieties available from different manufacturers.

Jordan or low angle conical refiner

The Jordan refiner which is manufactured by a number of companies is still found in many fine paper mills but has a number of drawbacks when compared to the modern conical and double disc refiners.

*High no load power which equals low operating efficiency. Typically in many installations the efficiency is less than 50%.

*Lack of flexibility in that there are a limited number of different fillings for these refiners.

* The fillings tend to have few bars and so refining intensity is high and not suitable for short fibred pulps.

Wide angle conical refiner

This refiner is found in many mills and has a reputation for robustness. A particular feature of one of the wide angle refiners is the "Develomax" filling which simulates the action of a basalt lava filling, giving a very low SEL. This type of filling is found on a number of tracing and glassine producing machines.

Shallow angle conical refiner

The 'Conflo' refiner is the most modern design of conical refiner. The advantages claimed for this refiner are low no load power and a long refining zone. The construction is such that the outer casing is also the shell which decreases time for filling changes.

The groove depth is relatively shallow which reduces the no load arising from pumping. The fillings for this refiner can have a greater number of patterns than other types of conical refiner.

Comparitive efficiencies

Typical operating parameters, measured by Pira International, for the different conical refiners of similar throughput are compared in **Table-2.**

*Excluding special "Develomax" filling

Table-2			
Operating Characteristics			
	Jordan	Wide angle	Conflo (JC 01)
Motor power (kW)	263	250	200
No load power (kW)	132	85	35
Rotation speed (rpm)	419	360	740
Efficiency (%)	50	66	82
Cutting edge length (km/s)	30-80	23-125*	30-150

This table shows that the Conflo has a higher rpm motor which increases the cutting edge length and makes the refiner the best conical refiner for the refining of hardwood. In spite of the higher rotation speed the Conflo has a lower no load and much higher efficiency than conventional conical refiners.

The Conflo refiner is therefore an energy efficient replacemtnt for older conical refiners and offers a range of fillings which are suitable for softwood and hardwood pulps.

Example

The refining system on a UK fine paper mill machine had four wide angle refiners. In normal operation three refiners were used to treat the stock. The three refiners were normally operated at maximum power and required 282 kWhr/te (gross) to supply 157 kWhr/te (net). The refiners were considered to be oversize for the flows used and replacements were considered.

After initial trials the original four refiners were replaced by three Sunds-Jylha JC-01 refiners and it was then possible to treat the stock with two of these refiners to achieve the same properties. Gross energy was now 167 kWh/te in supply 108 kWh/te net an overall saving of 115 kWh/te.

Double disc refiner

The double disc refiner offers a greater efficiency than older types of conical refiner and greater potential for treatment because of the two zones in the refiner. The refiner also offers a considerable degree of flexibility in operation because of the diversity of plate design offered. Standard fillings offer (for a similar size) a similar range of bar length to the Conflo refiner. The difference is that the disc refiner offers a large number of short bar impacts where as the Conflo refiner offers a lesser number of long bar impacts.

The two zones of the double disc refiner allow a high energy input per refiner for a given SEL. This means that a number of Jordan refiners can theoretically be replaced by one double disc refiner. For example to treat stock to an SEL of 1.0 Ws/m with a net energy input of 100 kWh/te (net) to achieve the properties for a printing paper on a 1.0 te/h machine would involve the use of 4 Jordan refiners operating at 220 kWh/te (gross).

One 24" diameter double disc refiner could supply the same net energy with improved properties operating at 175 kWh/te (gross) a saving of 45 kWh/te.

Similarly, a Conflo refiner, of equal size could supply the same net energy at 135 kWh/te (gross) a saving of 85 kWh/te.

Monoflo and duoflo

Having two zones, a double disc refiner can be internally configured for series or parallel operation, known as monoflo or duoflo stock flows through each zone simultaneously. In duoflo the refiner has twice the capacity.

By blocking or unblocking the passages through the rotor a double disc refiner configuration can be changed from duoflo to monoflo and vice versa. This can be necessary where fibre usage changes, eg increased hardwood or reduced softwood content, to allow modification of the characteristics of each refiner. With duoflo operation it is easier to maintain equal gaps in the two zones.

The multidisc refiner

It is generally considered that an SEL of less than 0.5 Ws/m is needed to treat short fibred pulps. These pulps include virgin hardwoods, mechanical pulps and some wastepaper grades. Although this intensity can be achieved with standard refiners the operation is not energy efficient.

As an example if one considers a system treating 4 te/h to a net energy of 100 kWh/te then, with the finest fillings available:

* a 24" double disc system with an SEL of 0.4 Ws/m would need four refiners at 170 kWh/te (gross).

* a conical system using Sunds-Jylha 01 series refiners would need eight refiners at 160 kWh/te (gross).

Apart from inefficiency the capital costs of such systems would be prohibitive. The first production solution to this problem was the Beloit 'multidisc' refiner. The approach here is to increase the number of bars in the refiner while maintaining disc size and refiner rotation speed. The increase in the number of bars is due to increasing the number of rotating and stationary elements from two of each to eight of each.

The multi-disc refiner consists of alternate stationary and rotating elements. Stock enters the machine through an inlet port to the centre of the machine housing along the axis of the main shaft. Both rotors and stators are capable of axial movement such that stock can distribute itself between the refining interfaces and exit.

The double disc refiner has two zones whereas the multi-disc can have up to eight zones. This results in an ability to achieve an intensity which is 25-30% of the normal lower limit of a double disc refiner and, because of the sperad of power across a multiplicity of zones, a greatly extended filling life. In comparison with conventional fillings a multidisc in production has achieved 8-10 times the lifetime of the double disc it replaced.

Example-

In one mill a 20" multidisc refiner replaced two 24" refiners with a saving in energy of 100 kWh/te. For a paper machine in another mill the need was for one conical and two double disc refiners, one 26" and one 24", to treat the same throughput of hardwood as the single multidisc.

OPERATIONAL PARAMETERS

No load power

Because of its contribution to the efficiency of a refiner the no load has a major influence on the use of energy in stock treatment. The no load power of a refiner can be changed by the condition of the refiner, stock throughput and condition of the fillings.

Some typical efficiencies for a similar throughput are given in **Table-3.** (Pira data) These efficiencies have been measured over a period of years on a number of separate installations.

Table-3 is representative for refiners in good condition operating with correct flow. In all cases no load is taken with stock flowing normally and the refiner with fillings in the fully backed off position.

Table-3

Comparison of relative efficiency

	Total power (kw)	No load power (kw)	Efficiency (%)
Jordan	263	132	50
Claflin 202	261	100	62
Conflo JC02	250	50	80
24" double disc	262	65	75
26" double disc	400	110	77.5

Refiner condition

In many installations with older Jordan refiners backing off refiners does not change the power reading at all. As no loads are rarely measured this is not observed and the refiner is seen as 'not doing its job' Refurbishment of the refiner in these cases can lead to large savings in energy.

Stock throughput with double disc refiners

Refiner fillings for a double disc refiner are designed for a specific stock throughput, normally specified as volumetric flow in litres/minute. The range of flow capacity, which is determined by the bar angle, can be between 50% and 110% of that specified. The central rotor is allowed to float to maitain an equal gap between discs in each zone.

However with incorrect flow the equalisation of gap is affected. This is particularly obvious in double disc refiners in monoflo (series) operation but also happens in duoflo mode. Using the notation in **figure 6**, when flow is below the capacity of the plates, number 1 and 2 discs are pulled together giving the equivalent of a single disc refiner plus a high no load due to friction between the plates. If flow is too high then numbers 3 and 4 discs are pulled together with the same effect. The occurrence is obvious by the noise at no load, but as many refiner systems are located in remote places it is not always noted. Where the refiners are in good condition the problem is self rectifying but where bearings are worn and sliding mechanisms rusted together the plates stay together giving a result which is not as expected.

The means of prevention is to measure no load at a regular interval, eg once per shift, and to maintain the refiners regularly. Where there have been significant changes in flow then the manufacturer should be contacted to see if changes in pattern are needed.

Example

As part of a refiner assessment of a paper mill the condition of each refiner was measured. Of most importance were the 26" double disc refiners which carry out most of the refining on two of the machines. At the time of the study it was noted that no loads for the two refiners were 195kW and 210 kW respectively, giving efficiencies of 35% and 30% (compare with Table-3).

Subsequent investigation showed that the sliding assemblies were worn and in the case of one of the machines at no load there was plate contact as evidenced by noise. Also the plate angles were designed for a higher flow which contributed to the high no loads through plate contact on the machine.

The problem was addressed in two ways:

* at the time of fitting new fine barred plates the bar angles were changed to cover the range of flow currently in use.
* new quill assemblies and hearing were fitted end the refiners generally refurbished.

After the changes the no loads of both refiners on PM1 and PM2 were the same at 158 kW, an efficiency of 47%. In terms of energy used the saving is, on average 27 kWh/te on PM1 and 42 kWh/te on PM2. The extra available power enabled machine speed increases.

Filling wear

The no load power of a refiner is dependent on groove depth which affects the hydraulic capacity or pumping action of the refiner. When a filling is very worn the grooves disappear and pumping ability is lost. The resulting low no load gives an appearance of efficiency but in operation of the refiner has ceased to be effective.

Example

Studies on a refiner system in a UK mill using two refiners in series showed that the no load of refiner #1 was 57 kW while the no load of refiner #2 was 83 kW. Assuming the #2 refiner to be in bad condition an inspection was made but the fillings were unworn and operation was satisfactory. The #1 refiner was then inspected to identify the reasons for 'efficient operation' and the fillings were found to be completely worn. Under normal operation both refiners were run at 260 kW each and so the #1 refiner would have had a higher SEL than the #2 refiner leading to strength deterioration which would eventually have been rectified by increasing the energy levels. On replacement of the worn fillings the no load of #1 equalled that of #2 refiner.

Residence time/throughput

The residence time in a refiner is determined by a number of factors, ie throughput, direction of angle and whether fillings are dammed, preventing flow across the grooves. Dams in fillings are a part of 'refining lore' but there is little evidence to support their efficiency.

Where a refiner is oversized and there is cavitation, the fibre mat between plates will be thin and at some times non existent. Although in most systems refiners may be initially correctly sized, problems can occur where different grades, of different deckles, are made on one machine. In this case the throughput can vary beyond the range of filling and refiner capacity.

Correct fillings can resolve some of the problem but the best solution is to keep flow through the refiners constant by means of recirculation loops. With a recirculation loop stock is returned to the inlet of the pump. As stock flow requirements are changed the control valve will alter the degree of recirculation and flow through the refiner remains constant. The loop can be pressure controlled which avoids the possibility of fillings clashing because of low flow condition. However a disadvantage of this system is that, as demand for refined stock varies and the recirculation flow alters appropriately the treatment of the stock varies.

Consistency

The major effect of changes in consistency is the change in throughput. In most cases where mills have consistency control the variation is small. The reason why energy control is preferable to power control is that changes in consistency (and flow) are corrected for.

The effect of consistency is greater for a hardwood than for a softwood pulp because of the greater strength of the softwood fibre. Practical experience shows that over the range of 4-6% softwood refining consistency should be toward 4% whilst hardwood should have a consistency toward 6%.

Refiner filling configuration

Bar dimensions

The power applied to a refiner determines the type of fibre treatment. As the power applied also determines the energy applied then it is obvious that one cannot be changed without the other. This can lead to problems where, because of changes in flow and/or consistency, more refiner energy is required to achieve a stock property, eg wetness or paper properties, eg porosity. The problem is more commonly seen where machine output has increased or furnish properties have changed over a period of time without changes to the refiners.

The problems can be particularly acute where a system has only one refiner in this case maintaining the energy level with increased throughput will lead to a deterioration in property. In order to maintain specification much more power (and therefore energy) is needed. Al this point energy has increased and treatment defined in terms of SEL has altered.

The solution to the problem is to change the refiner fillings Use of a finer bar pattern, giving more bars for a given area would, at the original flow, lead to a trend towards an improvement in properties, in this case strength. Now, at the original flow, specification can be maintained by reducing energy.

Example

A refiner system on a tissue machine consisted of a disc refiner on the virgin fibre line with a machine refiner later in the system.

Trials on this system where power was increased in order to improve properties demonstrated that, after a certain point, gains in tensile were minimal. The refiner fillings were changed to a finer pattern in order to give a more balanced treatment.

In this case the increase in tensile was the objective and was gained without an energy penalty. In other situations where tensile is not a problem then an equivalent tensile could be achieved at an energy saving of 30 kWh/. As machined discs were in use the change in fillings involved a recutting cost only, giving a 6 month pay back period.

Disc diameter

Until relatively recently fine paper furnishes contained more long than short fibre.Typical ratios were 70:30 or 60:40 softwood to hardwood. Over the last 20 years this trend has reversed and furnishes can now contain up to 90% hardwood. This reversal in papermaking practice can cause flow problems.

Example

Consider a mill originally designed to refine separately a furnish of 60% softwood and 40% hardwood at a throughput of 3 te/h and consistency 4%. In this case total volumetric flow will be 1250 litres/min divided as 750 litres/min through the softwood refiner and 500 litres/min through the hardwood refiner. In order to treat these flows 24" double disc refiners are used with 410 to 900 litres/min capacity fillings.

Now assume that the furnish has changed to 20% softwood and 80% hardwood with a machine increase (quite common) of 10%. Flow through the refiners is now 3.3 te/h or 1376 litres/min. Flow through the softwood refiners is 274 litres/min and through the hardwood refiners 1102 litres/min. The softwood flow is well below plate capacity and the hardwood flow well over.

For the hardwood refiners angles can be changed in order to cope with the increased flow. The softwood refiners are however close to the minimum capacity of a 24" double disc refiner. This problem can be solved by reducing the disc diameter to 20" either by fitting 20" discs with blanking plates or removing the bars from the existing 24": filling to a 20" radius. The result of this is shown in **Table-4.**

Table-4

Relation between filling diameter and no load

	24" filling	**20" filling**
Total power (kw)	350	350
No load power (kw)	95	57
Efficiency (%)	73	84

At a throughput of 1.1 te/hr the energy saving is 34.5 kWh/te.

Rotor/Stator Crosing Angle

The cutting angle of a filling determines the propensity to cut or fibrillate-low crossing angles promote cutting, high crossing angles promote fibrillation. The reasons for this may be explained as follows: when the angle is changed the number of bars of the same width which can be fitted into a given size of plate also change. Considering a filling of equal groove and bar width changes in angle will have the following effect **(Table-5).**

Table-5

Effect of changing bar angle for 34" Double disc 2-2-4 (Imperial) fillings

Angle	Cutting edge length (km/sec)	Specific edge load Ws/m (@300 kW.h/t
5°	102	2.9
10°	125	2.4
15°	165	1.8

As may be seen the change in cutting angle has changed the specific edge load at a given power although the type of filling (2-2-4) has not apparently changed. Cutting angle also determines the flow characteristics of the filling. The capacity of a refiner may be changed by changing the angle.

Rotation speed

The rotation speed of a refiner affects no load and refining intensity. In most cases motors have fixed speeds which depend on the size of the refiner. Speeds are recommended by refiner manufacturers and there is an interaction between rotation speed, allowable applied power and no load. As the rotation speed of a refiner is increased the allowable applied power also increases as does the no load power and therefore the amount of effective refining power is not increased by equivalent amounts

There are instances where refiners are fitted with variable speed motors for flexibility of operation.

Example

The example shown here is for a Sunds-Jylha JC-00 conical refiner with two types of filling available, one relatively fine barred (AA) the other coarser (BB) for a cutting action. Speed can be varied from 750 to 1200 rpm with maximum power of 51 kw at 750 rpm to 90 kw at 1200 rpm. **Table-6** shows the effect of the changes in rotation speed on intensity and no load for both fillings.

and the whole refined to the desired specification.

Table-6							
Relationship between rotation speed, no load and intensity							
AA filling = 1.80 km/rev				BB filling = 0.90 km/rev			
Assume 1 te/h throughput with a 90 kw. motor							
Filling	Speed (rpm)	Cutting edge length (km/sec)	Total Power (kw)	No load (kw)	Gross energy (kWh/te)	Net energy (kWh/te)	SEL (Ws/m)
AA1	750	22.5	51	11	51	40	1.78
AA2	1000	30	70	20	70	50	1.67
AA3	1200	36	90	33	90	60	1.67
BB1	750	11.3	51	11	51	40	3.56
BB2	1000	15	70	20	70	50	3.33
BB3	1200	18	90	33	90	60	3.33

These figures show that, for a given filling, changes in refining intensity as defined by SEL are very small and what is of most importance is the change in available energy; at higher speeds it is possible to apply more energy to the stock. However the efficiency changes from 79% to 65% as speed changes from 750 rpm to 1200 rpm.

REFINER INSTALLATION ARRANGEMENTS

Mixed and separate refining

The methods of refining a mixture of softwood and hardwood may be described as follows:

* Mixed refining- all components treated equally in the same refiners.
* Split mixed refining- where there are two or more refiners in line, set the first refiner up to treat the softwood component correctly and the second and subsequent refiners to treat the softwood component correctly and the second and subsequent refiners to treat the hardwood component.
* Sequential refining- The softwood component is refined separately then the hardwood added and the whole refined to the desired specification.
* Separate refining- Components are refined individually to their best advantage using optimum treatment.

Example-

The refining system on a paper machine was set up as a parallel/series system using three double disc refiners. There are other problems associated with this type of layout which will be discussed in the next section. The refining system was completed by two wide angle conical refiners running in parallel in the machine refiner position as a final control of stock properties.

With this system the normal practice was to use the three double disc refiners and either or both of the machine refiners. On two of the main products, parameters for the system averaged over nine months were as follows:

* Product A — Average throughput 7.8 te/h; Gross energy 175 kWh/te
* Product B — Average throughput 7.7 te/h; Gross energy 179 kWh/te

There were a number of disadvantages in the system which could be solved in a number of ways. The method chosen was to go to separate refining of the softwood and hardwood components. In this case no new refiners were necessary but an extensive change of pipework was involved. The new system layout is as follows:

*** Softwood refining**

One double disc refiner fitted with fillings to give correct flow and intensity. Two wide angle conical refiners as backup, fitted to the softwood line as this type of refiner is preferable for longer, tough fibres. All refiners are in series.

*** Hardwood refining**

Two double disc refiners installed in series fitted with fine barred fillings to give as low intensity refining as practicable.

In operation one of the conical refiners has been found unnecessary and the machine normally operates with the three disc refiners with occasional need for one of the conical refiners on the softwood line.

On the same two products the parameters for the system, again averaged over a nine months after the change are:

* an increase in throughput of 7% to 9%
* a decrease in gross energy of 26% on average or 45 kWh/te.

In this case as the existing refiners were used the payback was six months. Where replacing a system because of obsolescence or wear the payback would be about 4 years.

Series or parallel operation

In systems containing more than one refiner in line there are a number of types of installation, ie series, parallel and combination systems.

The use of the combination system arose from a belief that only two refiners could be operated in series. Therefore where flexibility of operation involved the use of more than two refiners in line either parallel installations or that shown above were used. The system is certainly flexible in that series or parallel operations can be used if only two refiners are needed. There are now a number of systems where three refiners are used in series.

The major disadvantage of both systems involving parallel operation is the control of flow through the refiners. Another disadvantage is the use of different powers on refiners because of differences in flow. Even where pipes are of equal size, it is difficult to obtain equal flows through refiners in parallel.

Example

The refining on a paper machine in a UK Mill used a series/parallel operation with double disc refiners to treat a mixed furnish. The three refiners were equally sized with the same fillings. A study of this system showed that the flows through the parallel refiners could have a 32% difference between refiners 1 and 2. All fillings were sized for full flow and so the fillings in the parallel refiners were undersized.

The system as shown has the following characteristics:

* unequal energy input for each refiner leading to heterogeneous action and product quality variation
* refining intensity which is too low for a softwood/hardwood mixture
* uneven flow through the refiners in parallel.

The suggested modification was to change the system to have all three refiners in series but in fact, in series the system was found to operate satisfactorily with only two refiners, operating at higher load.

Using two refiners gives a more ideal refining intensity and a saving in energy of 15 kWh/te. There is also a spare refiner should the other need maintenance. The more homogeneous refining should give an improved property balance which could lead to greater energy savings. Actual savings cannot be given as the system was changed from parallel to series refining at the same time as the change from mixed to separate refining.

Basic refiner operation

It is fair to say that, unless the machine or refining system is fairly new, in many mills the operation and control of refining is more manual than automatic. This can lead to problems for a number of reasons:

* Many refiners are remote from the machine and are not under the control of the machineman; this can lead to control of drainage and paper properties by telephone which makes it difficult continually to maintain set conditions,

* Measurement is by ammeter, often at a point well away from the operative's attention.

* The only reference property is wetness of freeness often measured infrequently.

* Because of the remote position, unsatisfactory refining is not noticed until there have been a number of problems on machine.

Even the very simple step of installing the ammeter where the machineman can easily see it can make a big difference as does the provision of remote, manual control of refiners on the machine control panel. A refiner can often be changed from manual to electrical operation by a small motor and a chain sprocket on the handwheel.

Nowadays more sophisticated systems are available which can be beneficial in controlling refiner operation and reducing energy demand.

ENERGY CONTROL

Control of refining reduces the variation in use and reduces product variability. Also where a system is automatically controlled there is less tendency for the 'personal choice' type of control, ie where the refiners are set up to suit the preference of the person in change on that shift.

Refining may be controlled by a number of operating parameters. In most mills with automatic controls, power and energy are the commonest parameters to be controlled

NEW SYSTEMS

When designing new systems the fibre is considered first and last to give a system which gives the best option for a given furnish. Only after a complete understanding of the product and fibre use has been established should consideration be given to the types of refiner to be installed: The method of operation here is to:-

1. Quantify the existing system (s), perhaps from an initial optimisation study.

2. From the study establish future needs and set specifications (for the fibre)

3. Select refiner sizes and fillings for optimum energy use and product performance.

4 Select refiner manufacturers able to meet 2 and 3.

5. Check manufacturer trials using independent pilot plant.

6. Commission the system.

SUMMARY

When considering the optimisation of a paper mill refining system it is well worth checking existing equipment or consulting an independent expert before purchasing new equipment. Attention to parameters such as no load and correct sizing and design of refiner filling can yield considerable improvements in performance at low cost. Installation of remote operating and energy or power control systems will assist the operator to produce a consistent quality product. When new equipment becomes necessary care should be taken to know exactly what treatment the fibres used require and then sizing and installing systems accordingly.

However with incorrect flow the equalisation of gap is affected. This is particularly obvious in double disc refiners in monoflo (series) operation but also happens in duoflo mode. Using the notation in figure 6, when flow is below the capacity of the plates,number 1 and 2 discs are pulled together giving the equivalent of a single disc refiner plus a high no load due to friction between the plates. If flow is too high then numbers 3 and 4 discs are pulled together with the same effect. The occurrence is obvious by the noise at no load, but as many refiner systems are located in remote places it is not always noted. Where the refiners are in good condition the problem is self rectifying but where bearings are worn and sliding mechanisms rusted together the plates stay togother giving a result which is not as expected.

The means of prevention is to measure no load at a regular interval, eg once per shift, and to maintain the refiners-regularly. Where there have been significant changes in flow then the manufacturer should be contacted to see if changes in pattern are needed.

Filling wear

The no load power of a refiner is dependent on groove depth which affects the hydraulic capacity or pumping action of the refiner. When a filling is very worn the grooves disappear and pumping ability is lost. The resulting low no load gives an appearance of efficiency but in fact operation of the refiner has ceased to be effective.

Example

Studies on a refiner sytem in a UK mill using two refiners in series showed that the no load of refiner # 1 was kW while the no load of refiner # 2 was 83 kW. Assuming the # 2 refiner to be in bad condition on inspection was made but the fillings were unworn.