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A Practical Method for Predicting High Consistency Refiner Plate Performance

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OVERVIEW

- Refiner plate design can affect the steam generation point.
- Excessive steam pressure can interrupt material flow into the refiner.
- Correct dam placement and taper selection can significantly improve refining performance.
- Effective Open Area analysis removes many trial-and-error methods previously associated with refiner plate optimization.
- Refiner design requirements determine the optimum shape of the EFA curve as well as the steam pressure peak.

Introduction

As the size and complexity of high consistency refining systems – and the related cost of plant downtime – continue to increase, it becomes crucial to optimize operating efficiencies while minimizing operating delays.

Consistent pulp quality is a result of stable refiner operation. Plate design must provide stable operating life and avoid plate-to-plate contact. Through correct metallurgy selection and quantitative analysis of plate design, it is possible to systematically approach refiner plate optimization.

This edition of *Optima* explores the effects of steam pressure, plate dams and plate taper on the refining process and refining intensity. In addition, a method is provided which quantifies various plate design parameters.

The Effects of Steam on the Refining Process

The main refining process occurs approximately 2/3 to 3/4 of the distance from the inlet to the outlet of the plate. At this point, sufficient energy has been transferred to the fiber/water mixture to create steam (Fig. 1). More than two tons of steam are produced for every ton of pulp in most TMP applications.

Steam generation is accompanied by a localized pressure build-up as the steam tries to escape. If this is excessive, the pressure forces the steam back toward the inlet, interrupting pulp flow into the plate. Once the steam reaches the inlet and escapes, pressure is relieved. This rapid, cyclical build-up and release of steam pressure may cause axial vibrations which can create load swings of more than 20%, non-uniform refining action, and, in some cases, plate clashing.

For peak operating efficiency, most of the generated steam should flow forward with the pulp to the plate's outlet. An efficient plate design, utilizing effective dam and taper selection, will minimize backflow of steam and provide for good loading with low vibrations.

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The Effects of Dams

The correct placement of surface dams around the Steam Generation Point helps confine the steam. However, excessive damming can also create critical levels of steam pressure, causing steam blowback.

The refiner plate must be designed to hold the "pulp mat" back at the point of maximum steam pressure. This is accomplished with dams placed in the grooves. (Fig. 2 shows some common dam profiles.)

Generally, surface dams are used in the Maximum Steam Pressure Zone and sub-surface dams are used elsewhere. Dams have several effects:

- Reduce Channeling (i.e. reduce shives)
- Promote Fiber Pad Between Plates
- Increase Closing Pressure, May Increase Load Variation
- Increase Chance of Groove Plugging

Fig. 1: Steam Pressure Curve During Refining

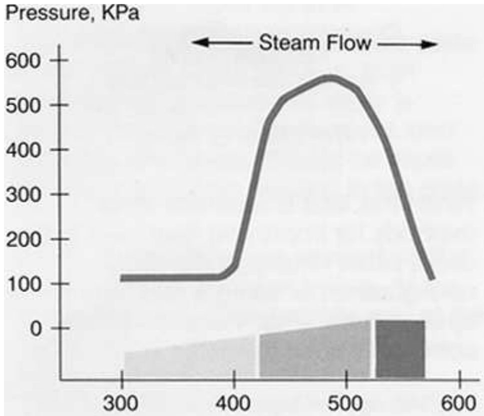
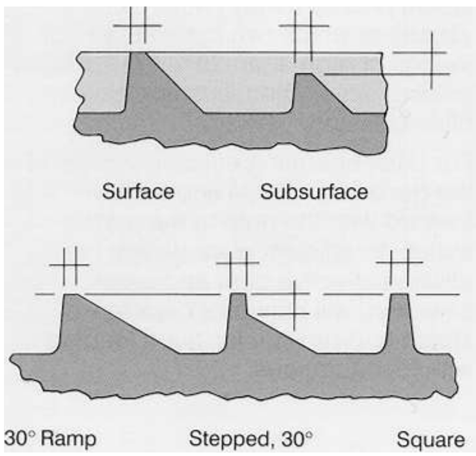


Fig. 2: Dam Profiles



The Effects of Taper

Plate taper is typically used to promote feeding of the refiner (Fig. 3) and to compensate for some O.D. disk deflection, but there is a corresponding reduction in peripheral gap with steeper tapers. This reduction tends to "pinch off" the forward flow of steam, creating a practical limit to the amount of taper.

When this limit is reached, other methods for improving flow have to be used, either changing the dam configuration or using a new, more open pattern. (Fig. 4 depicts some commonly used tapers.)

Increasing the taper moves the steam pressure toward the periphery, since an increasing proportion of the work is done in the outer zones of the plate.

Effective Open Area: Determining Resistance to Flow in Various Plate Zones

High consistency refining is very complex, due to the formation of steam and the resulting two-phase flow.

A logical engineering approach, the ***Effective Open Area (EFA)*** produces a curve representing the relative resistance to flow for each zone of the plate. The resistance terms are applied to each of the actual (or geometric) open areas A_o of each plate zone, in the following manner:

EFA = A_o x (G_c x D_c)
Where:
EFA = Effective Open Area
A_o = Geometric Open Area
G_c = Groove Coefficient
D_c = Dam Coefficient

(The Geometric Open Area is demonstrated in Fig. 5.)

Fig. 3: The Effect of Taper

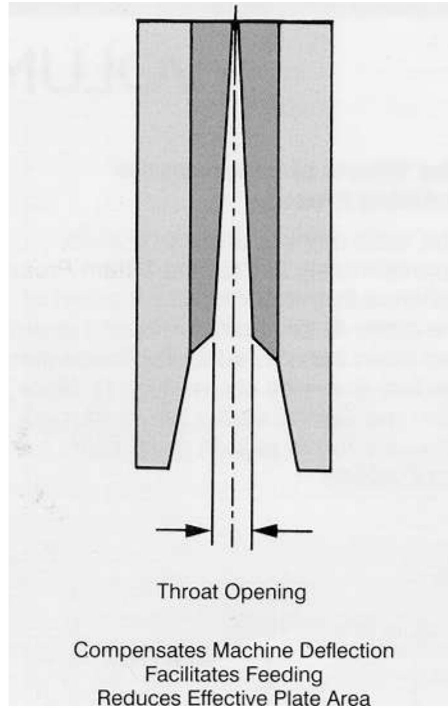


Fig. 4: Taper Profiles

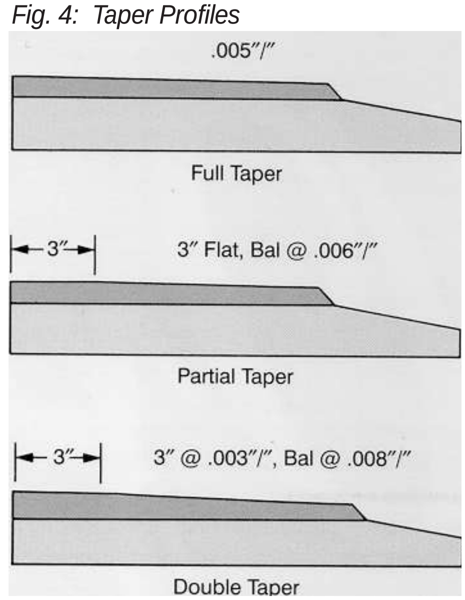
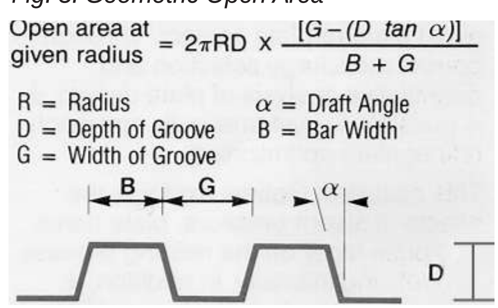


Fig. 5: Geometric Open Area



How EFA Works in Practical Applications

The 42SW118 plate is shown in Fig. 6a. ***EFA*** analysis of this plate is shown in Fig. 6b. The ***Geometric Open Area (GOA)*** in the "B" zone varies from 12 to 13 sq. inches, compared to an ***EFA*** of 4.0 to 4.5 inches, 30% of the ***GOA***. This 30% factor is a measure of the effective flow resistance of the individual grooves and dams. Since there are no dams in zone "A", the resistance factor is over 50% due to groove geometry only. There is also less difference between ***GOA*** and ***EFA***.

The 42SW121 plate is shown in Fig. 7a. ***EFA*** analysis of this plate is shown in Fig. 7b. Zones "B" and "C" both have sub-surface dams, while the dams in zone "A" are surface. Therefore, there is a slight step between zones "B" and "A" because of the increased resistance provided by the surface dams in zone "A". The average resistance factor in "C" and "B" is 30%; in zone "A," 23%.

The Effect of Taper on EFA

The above examples assume the plate is flat with no taper. Since, in high consistency applications, taper is present to promote feeding and load stability, allowances should be made for the actual taper applied to the plate.

In Fig. 8, the taper has opened up the plate's ***EFA*** at the inner radius. At the same time, the plate-to-plate gap at the outer radius has been reduced. This offsets the loss of effective surface-bearing area in the inner areas of the tapered plate. The result: a reduced ***EFA*** in zone "A" in Fig. 8, compared to Fig. 7b.

In Fig. 9, the taper was 2" FLAT/BALANCE @ 0.010"/". The increased support given by the 2" FLAT area opens up the plate-to-plate gap. With the plate gap increased, the ***EFA*** is also increased in zone "A". Also, the remaining taper, which is 0.010"/", opens the plate up in zone "C" from 2.8 to slightly over 3.0 sq. inches, promoting feeding of material into the plate.

Fig. 6a: Layout of 42SW118 Plate

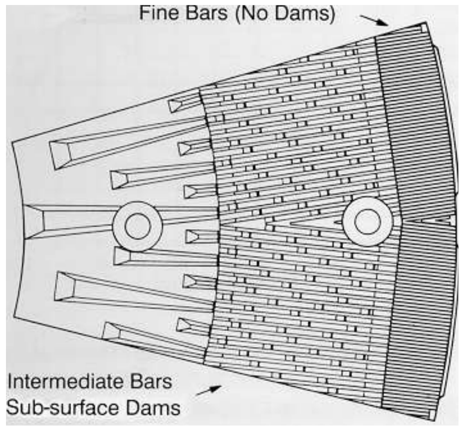


Fig. 6b: Geometric & Effective Open Area Curves – 42SW118 Plate

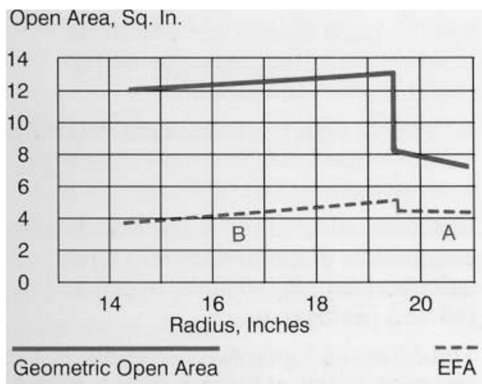


Fig. 7a: Layout of 42SW121 Plate

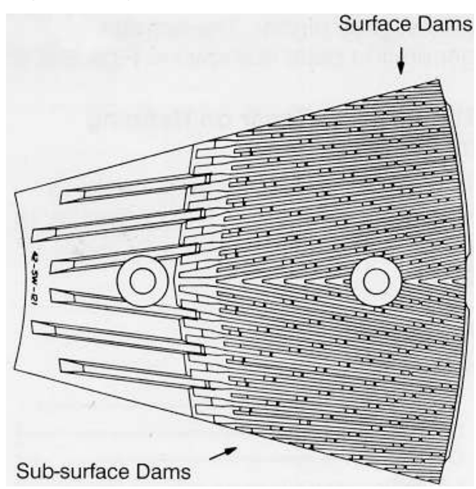


Fig. 7b: Geometric & Effective Open Area Curves – 42SW121 Plate

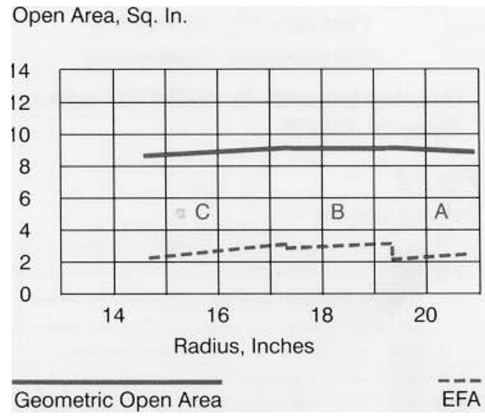


Fig. 8: Effective Open Area Curve for 42SW121 with a Constant Taper of 0.005"/"

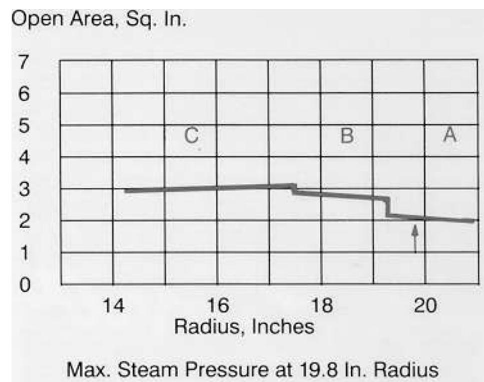
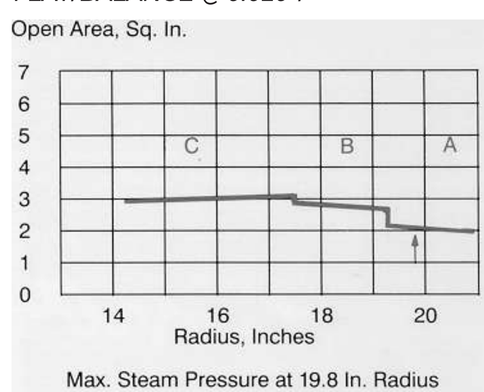


Fig. 9: Effective Open Area Curve for 42SW121 with a Compound Taper of 2" FLAT/BALANCE @ 0.010"/"



The Effect of Taper on Steam Generation

As discussed earlier, excessive steam pressure can interrupt the feeding of material and the operation of the refiner. As shown in Fig. 11, the flatter taper used in Fig. 9 drives the steam generation point further away from the exit. Because of this, steam pressure is also slightly higher. The actual steam generation point is shown in Figs. 8 & 9.

The Effect of Taper on Refining Intensity

To estimate a specific plate design's refining performance, it is necessary to estimate the refining intensity (Figs. 12 & 13).

The reduction in refining intensity shown in Fig. 13 is due to the flattening of the taper. (Refining becomes more evenly distributed over a larger area of the plate.)

Fig. 10: Steam Generation Diagram for 42SW121 with a Taper of 0.005"/"

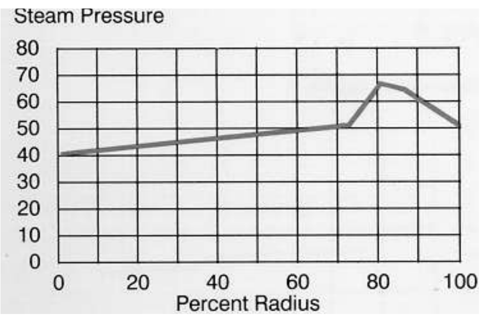
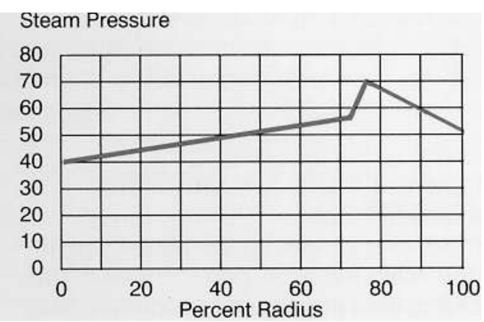


Fig. 11: Steam Generation Diagram for 42SW121 with a Taper of 2" FLAT/BALANCE @ 0.010"/"



Generally, the refining intensity is higher in primary refiners vs. secondary and reject refiners. Since plate taper affects refining intensity, changing the taper can sometimes create a plate design suitable for both positions. However, since a taper change also causes a change in steam pressure, it is not always possible.

Fig. 14 demonstrates a real-life example. The mill experienced load swings following a system throughput increase. This increase created more steam and more steam pressure, resulting in severe blowback. Pressure was relieved by grinding down the outer rows of dams from surface to subsurface and increasing the taper at the inlet to promote better feeding.

Summary

Refiner plate design can affect the position and the magnitude of the steam generation point.

Excessive steam pressure can interrupt material flow into the refiner, causing load swings of 20% or more.

Effective utilization of surface and sub-surface dams and correct taper selection can significantly improve refining performance.

The Effective Open Area analysis removes much of the previous trial and error methods associated with refiner plate optimization.

Different refiner types have their own unique design requirements that determine the optimum shape of the EFA curve as well as the steam pressure peak.

Fig. 12: Refining Intensity for 42SW121 with a Taper of .005"/"

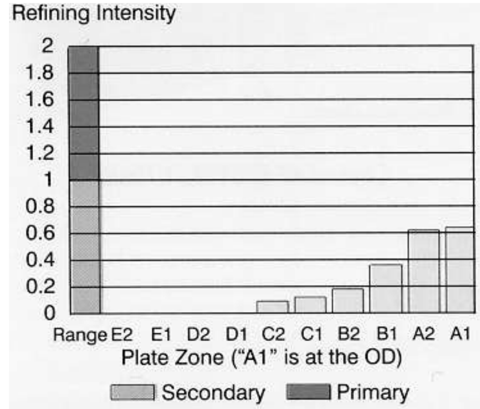


Fig. 13: Refining Intensity for 42SW121 with a Taper of 2" FLAT/BALANCE @ .010"/"

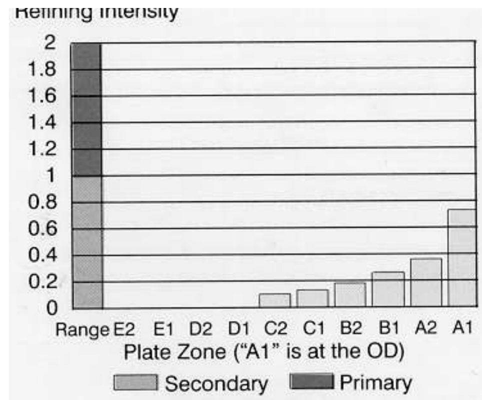
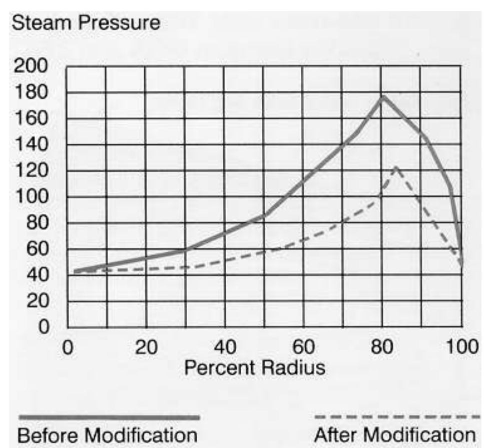


Fig. 14: Effect of Taper and Surface-Dam Change on the Position and Magnitude of the Steam-Pressure Peak



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