OPEN DISCHARGE PULP REFINER

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Filed: May 20, 1974

Appl. No.: 471,473

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ABSTRACT

Open discharge, low consistency, paper pulp refiners are provided with refining plates having a pumping or positive beater bar angle to the plate radius of from 5° to 25°, feed grooves in the face of at least one of a plate pair being plugged at the outer plate periphery and the width of the beater bar flow channels sufficient to balance centrifugal flow forces on the pulp stock tending to accelerate said stock therethrough.

12 Claims, 6 Drawing Figures
OPEN DISCHARGE PULP REFINER

BACKGROUND OF THE INVENTION

1. Field of the Invention
The present invention relates to low consistency wood pulp refiners of the plate or disc type having an open, non-pressurized discharge. More specifically, the present invention relates to the beater bar design configuration of plates having unique utility in combination with such open discharge refiners.

2. Description of the Prior Art
In the preparation of wood pulp for papermaking, cellulosic fibers are subject to a series of mechanical working or shearing operations prior to final web forming. Depending on the point in the pulp flow stream where such working takes place, the process may be characterized as deshiving, defiberizing, beating or refining. Furthermore, the range of consistency over which such working may be performed spans from approximately 2 to 30 percent; consistency being that percentage of dry fiber present in a total aqueous slurry. The art makes a rough distinction between low (generally less than 20 percent fiber) and high (generally more than 20 percent fiber) consistency working.

The equipment by which paper pulp is refined varies in design as much as the pulp working conditions. One such design employs fluid pressurization of the refining chamber. If the stock is pumped through the refiner against substantial fluid pressure, the process and equipment is known to the art as pressurized refining.

Open discharge refining describes those cases in which the fiber slurry, is discharged from the machine against local atmospheric pressure, usually directly into an unpressurized receiving vessel.

Further differences between pressurized and open discharge refining machinery of the disc type are found in the orientation of the bar design on the plates thereof. Pressurized refiners generally utilize a positive beater bar angle whereas open discharge refiners utilize a negative bar angle.

The term “positive angle” means that the plate beater bars are angled relative to the plate radius in a lagging direction. In other words, from a frontal viewing perspective of a pressurized refiner plate, the bars will be angled across the plate plane relative to a plate radius in such a manner that the outer plate periphery portion of the bar will lag behind portions of the bar more proximate to the inner plate periphery relative to the rotational direction.

“Negative angle” beater bars are angled relative to the plate radius and rotational direction whereby the outer periphery portions of the bars lead the inner periphery portions.

When a positive plate angle pattern is reflected in both plates of a cooperative pair, the relative shearing movement of a respective pair of beater bars imparts a radial outward movement to the stock.

The converse is true of a pair of negative bar plates: e.g. the wiping action of one beater bar passing in close proximity to a beater bar on the other plate imparts a radially inward force to the stock.

In the case of the positive angle bars, the bar shearing impetus augments the natural centrifugal impetus to the stock as a consequence of plate rotation.

In the case of negative angle bars, the bar shearing impetus counteracts the centrifugal impetus.

In either case, positive or negative angle bars, the shearing, wiping action between beater bars on respective plates of a pair is believed to contribute positively to the stock refining result over the result of straight radial bars.

While a net fluid flow pressure differential across the plate face is necessary to induce flow through any refining engine, regardless of bar angle disposition, only in pressurized machines is the pressure difference a variable that is controllable independently of stock supply pressure. Lacking such independent control over flow pressure differential, open discharge machines have, historically, been equipped with negative angle beater bars to restrict the stock flow rate therethrough. Such flow restriction was deemed necessary to prevent the machine, if provided with positive angle plates, from momentarily discharging stock at a greater rate than supplied. The consequence of an instantaneously greater discharge rate is flow cavitation between the plates thereby causing collision or bumping of the plates.

Unfortunately, the magnitude of flow restriction provided by negative angle plates increases progressively as the plates wear from use. Accordingly, the stock throughput capacity of a half worn, negative angle plate is much less than half the new plate capacity.

Although, negative angle plates offer improved refining action over straight radial plates, it has been discovered that positive angle plates offer even greater improvements. While the tendency of positive angle plates to bump may be prevented in pressurized machines, the same vehicle of prevention is not available to open discharge machines. Consequently, to simply equip an open discharge machine with positive angle plates of prior art design for refining quality gains is to invite the problems of plate bumping which are predominately represented by excessive plate wear rates and replacement expenses. Moreover, plate bumping can defeat the stock refining quality gains sought by positive angle plates in the first instance.


Assuming that one desired to provide an open discharge refiner with prior art positive angle plates, one obvious means of preventing plate bumping would be to sustain the stock feed flow rate at sufficiently high rates as to preclude cavitation. The solution, however, inherits the management difficulties of a minimum flow rate threshold for a machine.

Unfortunately, the flow rate threshold minimum to prevent plate bumping in open discharge plate refiners is not a fixed quality relative to the machine design and size, exclusively. The wood species and constituency of the stock blend strongly effect a minimum flow rate value. For example, a stock containing 50 percent pine will have a lower minimum flow rate through a particular refiner than a stock containing 15 percent pine.

Stock blend and flow rate flexibility are important economic variables to the sound management of an integrated, multiple produce, pulp and paper manufacturing facility. Accordingly, under the state of the prior art, a certain magnitude of managerial discretion is lost
by inflexible constraints on stock blend and flow rate when a choice is forced between the large capital expense of owning and maintaining more machines than otherwise necessary to achieve a given degree of stock refining or tolerating the economically high running consequence of rapid plate wear.

It is therefore an object of the present invention to teach a particular combination of plate design parameters including a positive beater bar angle to be used in further combination with low consistency, open discharge refining engines that will greatly reduce the minimum flow threshold through such refiners.

Another object of the present invention is to teach open discharge refiner plate design characteristics including a positive angle beater bars which, in use, will greatly extend the operational life of such plates.

Another object of the present invention is to teach the construction of an open discharge refiner plate having an unusually high energy transfer efficiency to the stock.

Another object of the present invention is to teach the construction of a positive angle, open discharge refiner plate requiring an unusually low application of plate pressure for a given magnitude of energy transfer to the stock.

SUMMARY OF THE INVENTION

These and other objects of the present invention are accomplished for low consistency, open discharge plate refiners by providing plates having a positive or pumping angle to the beater bars thereof in combination with a maximal number of beater bars, sufficient flow resistance along grooves between the beater bars to balance centrifugal forces on the stock, and an open discharge periphery at the bar groove terminus but a plugged terminus for stock feed grooves respective to a pie segment of parallel beater bars in at least one of a cooperative plate set.

Open discharge refiners equipped with plates of the present invention may be operated at extremely low plate loading pressures to develop a given stock freeness. Although comparatively less energy per weight unit of stock will be consumed by refining engines of the present invention, a greater percentage of that energy consumption will be transferred to the fiber objective.

BRIEF DESCRIPTION OF THE DRAWINGS

Relative to the drawings wherein like reference characters denominate like elements throughout the several figures:

FIG. 1 is a schematic section of an open discharge refiner of a type suitable for use in the invention combination.

FIG. 2 is a frontal view of a refiner plate segment according to the present invention.

FIG. 3 is a sectional portion of the present refiner plate taken from FIG. 2 at cut line III—III.

FIG. 4 is a sectional portion of the present refiner plate taken from FIG. 2 at cut line IV—IV.

FIG. 5 is a sectional portion of the present refiner plate taken from FIG. 2 at cut line V—V.

FIG. 6 is a frontal view of a refiner plate segment having a modified beater bar and feed groove orientation.
Relative to the direction of rotation, a feed groove 61 establishes the reference angle for beater bars 41 in the preceding 15° sector of the annular section 40. All beater bars 41 and channels 42 preceding a respective feed groove radius are parallel thereto. Consequently, the angle of each bar relative to a local radius progressively increases from 0° to 15°. For this reason, it is convenient to refer to an average bar angle of 7.5°.

Various permutations of factors affecting bar angularity may produce an average positive bar angle from 5° to 25°.

The outer annular section 50, characterized as the refining section comprises a beater bar angular orientation similar to that of the beater section. In this section, both, bars 51 and channels 52 are shown by FIG. 4 to be of identical width A at ⅛ inch respectively. For reasons of structural strength, a ¼ inch bar width is near minimum. Since one design objective is to provide as many beater bars as possible within the allotted area, it is, therefore, preferable to not greatly exceed or reduce this dimension. Channel width, however, is variable, for reasons to be subsequently explained.

The channel depth is 3/16 inch whereas the feed groove 61 depth is ⅜ inch.

Although the preferred embodiment of the invention disposes the feed grooves 61 along a plate radius, such alignment is not absolutely necessary. FIG. 6 illustrates an embodiment of the invention wherein feed grooves 63 are cut along a positive angle to the radius as an expedient to increase the average beater bar angle within the preceding 15° sector. Note from this embodiment that the divisional interface 64 between adjacent 15° plate segments do not follow the axes of feed grooves 63. Consequently, in the FIG. 6 embodiment, beater bars 51 and channels 52 rotationally preceding a respective feed groove 63 have a different angular orientation from bars and channels on the same segment but following the same feed groove.

The average beater bar angle may also be increased by increasing the angular arc of each radial section.

Specific dimensions are disclosed herein for the purpose of teaching dimensional comparatives for a single embodiment. It should be understood, however, that such dimensions are not of a limiting nature and may be altered by those of ordinary skill in the art without departing from the spirit of the invention.

Noteworthy of the refiner section 50 is the fact that channels 52 are continuous and uninterrupted to the outer plate periphery 33. Feed grooves 61, on the other hand, in at least one of a cooperative plate pair, are plugged by peripheral dams 53.

Although many facets of the aforesaid plate design are known and conventional, the particular combination described herein is unique in that it maximizes performance from a low consistency, open discharge machine.

There is also a conventional belief in the paper pulp preparation art that the mechanics of refining are of a frictional nature. Extensive studies, however, have revealed this belief to be unfounded in that the energy transfer mechanism to the stock fiber is by viscous dissipation e.g. energy transfer due to the presence of a shear field in a liquid medium. Such viscous dissipation decreases as the gap separation between the plates 10 and 20 decreases.

Plate pressure reflects the magnitude of squeeze film resistance and consequent pressure between opposite beater bar faces. The size of the individual area portions between two respective plate bars is the force magnitude determinant for a given squeeze film thickness. Accordingly, the smaller the individual area portions between two respective plate bars, the lower is the required plate pressure to maintain the same gap separation. As previously stated, the gap is the primarily relevant factor to energy transfer and pressure is merely the consequence of a given gap for a particular bar area pattern.

To optimize the plate pattern, it therefore follows that the refiner section 50 should be provided with a maximum number of minimum width beater bars.

An independent factor of relevance to the refiner section bar pattern is that of channel 52 flow area. The controlling objective of this factor is to balance the centrifugal force impetus to accelerate the stock movement along the channels with channel surface flow resistance. The primary instrument of flow resistance is channel width. A force balancing width, however, will depend on the particular stock characteristics and consistency. A ¼ inch channel width may be adequate for hardwood stock whereas a ⅛ inch width may be more appropriate for pine of the same consistency.

As previously stated, the channel terminus at the outer plate periphery 33, however, should be open and unobstructed.

On the other hand, the feed grooves 61 which supply stock to the foreshortened channels 52 opening thereinto are completely plugged on at least one plate of the cooperative pair and preferably on the rotor.

The mechanism by which a positive bar angle in an open discharge refiner will deliver superior refining performance is not completely understood. It is known however, that a primary objective of the prior art negative angle is to impede stock flow between the plate and reduce the minimum, cavitation threshold, flow rate. This objective may be obtained by other means, however, such as plugging the feed grooves 61 and minimizing the channel 52 flow area.

In developmental tests of 44 inch diameter plates for open discharge refiner engines of the aforesaid design operated at 500 rpm and having a positive bar angle of 7.5° on both, the rotor 20 and stator 10 but with the feed grooves 61 on the rotor 20 only plugged, the plate set gave 20 weeks of service on hardwood for a given stock slowness. Stock consistency was approximately 2–6 percent. Plate pressure and energy consumption was substantially reduced from prior art norms.

The normally expected useful lifespan of prior art plates on the same machines working the same stock flow ranges from 5 to 8 weeks.

Having described the preferred embodiment of our invention, it will be apparent that modifications thereof will occur to those skilled in the art within the scope of the appended claims.

We claim:

1. In an open discharge, low consistency, cellulosic stock refining engine having an unpressurized stock discharge conduit and a cooperative pair of planar, oppositely facing, relatively rotating refining plates, said plates having a circular outer periphery about an axis of rotation and being divided into inner and outer concentric annular sections, said annular sections being separated by a circular distribution groove into the face plane of said plates, said outer annular section being
further divided into a plurality of circle sectors, said sectors being separated by stock feed grooves into the face plane of said plates, said stock feed grooves extending linearly from said circular distribution groove to the proximity of said outer periphery, relative to a predetermined rotational direction for said plates, the improvement comprising:

A. a plurality of alternating parallel beater bars and flow channels extending across the face plane of said plates within a sector which is delineated by two angularly successive feed grooves relative to said rotational direction, the feed groove angularly leading said sector relative to said rotational direction being designated as the leading feed groove and the feed groove angularly trailing said sector relative to said rotational direction being designated as the lagging feed groove, a number of said channels within a respective sector being continuously open from said circular distribution groove to said outer plate periphery, the remainder of said channels within a respective sector being continuously open from the respective leading feed groove to said outer plate periphery; and,

B. said feed grooves terminating inwardly from said outer periphery thereof respective to at least one plate of a cooperative pair.

2. Apparatus as described by claim 1 wherein the average angle of said bars relative to a plate radius is between 5° and 25°.

3. Apparatus as described by claim 1 wherein said feed grooves are radial.

4. Apparatus as described by claim 1 wherein one plate of said cooperative pair is stationary, said feed grooves in the other, rotating, plate being plugged inwardly from said outer periphery.

5. Apparatus as described by claim 1 wherein the stack flow resistance within said channels is approximately equal to the centrifugal force on said stack within said channels when said plates are relatively rotating.

6. Apparatus as described by claim 5 wherein said bars and channels are approximately of equal width.

7. Apparatus as described by claim 5 wherein said channels are of greater width than said bars.

8. In an open discharge, low consistency, cellulosic stock refining engine having an unpressurized stock discharge conduit and a cooperative pair of planar, oppositely facing, relatively rotating refining plates, said plates having a circular outer periphery about an axis of rotation and being divided into inner and outer concentric annular sections, said annular sections being separated by a circular distribution groove into the face plane of said plates, said outer annular sections being further divided into a plurality of circle sectors, each of said sectors having an adjacent stock feed groove into said plate face plane between adjacent sectors, said feed groove extending linearly from said distribution groove to the proximity of said outer periphery, relative to a predetermined rotational direction for said plates, the improvement comprising:

A. each feed groove being disposed at an angle relative to a plate radius passing therethrough whereby the outer peripheral portion of the respective feed groove angularly trails the inner portion thereof relative to said rotational direction;

B. a plurality of alternating beater bars and flow channels across said plate face plane within said sectors angularly preceding an adjacent feed groove relative to said rotational direction and parallel thereto, a number of said channels being continuously open from said distribution groove to said outer periphery, the remainder of said channels opening into the feed groove respective to the next adjacent angularly preceding sector and being continuously open to said outer periphery; and

C. said feed grooves terminating inwardly from said outer periphery thereof respective to at least one plate of a cooperative pair.

9. Apparatus as described by claim 8 wherein the angle of said feed groove relative to a plate radius is less than 15°.

10. Apparatus as described by claim 9 wherein one plate of said cooperative pair is stationary, said feed grooves in the other, rotating, plate being plugged inwardly from said outer periphery.

11. Apparatus as described by claim 9 wherein the stack flow resistance within said channels is approximately equal to the centrifugal force on said stack within said channels when said plates are relatively rotating.

12. Apparatus as described by claim 11 wherein said bars and channels are approximately of equal width.
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,910,511 Dated October 7, 1975

Inventor(s) Philip J. Leider et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 43, following the word "taught"
delete "by" and insert -- in --; therefore.

Column 5, line 54, following the word "herein" delete the word "us" and insert the word -- is -- therefore.

Signed and Sealed this third Day of February 1976

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks
UNITED STATES PATENT OFFICE
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