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3,428,262

APPARATUS AND PROCESS FOR REFINING PAPER STOCK

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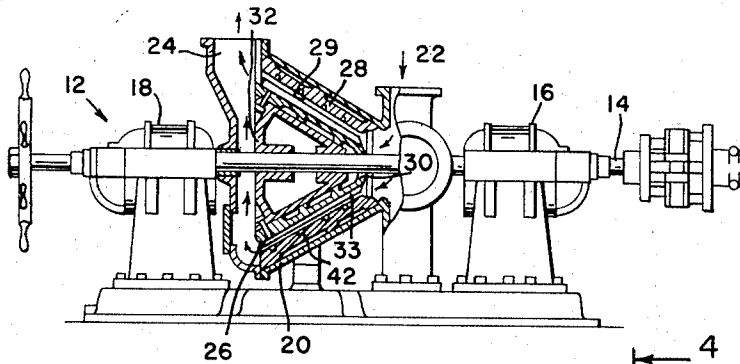


Fig. 1

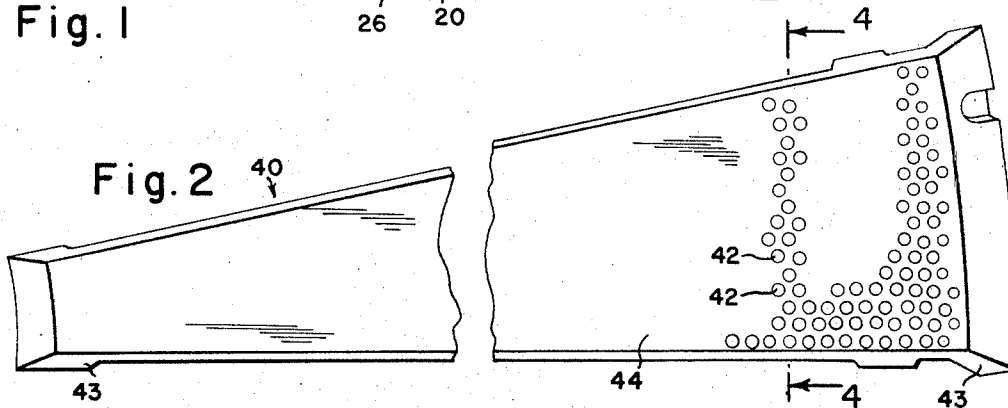


Fig. 2

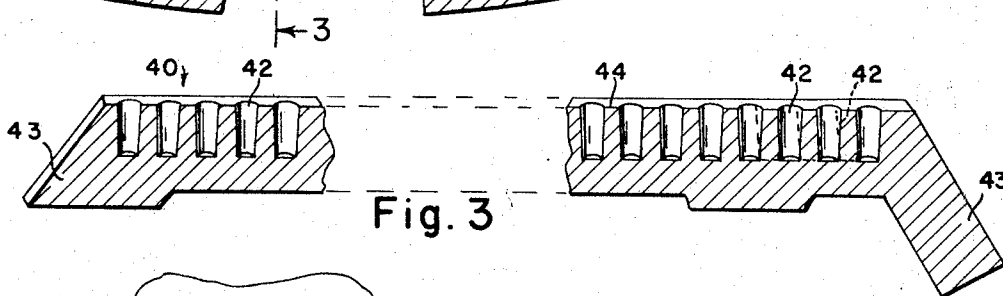
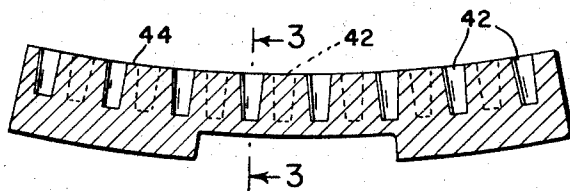


Fig. 3

Fig. 4

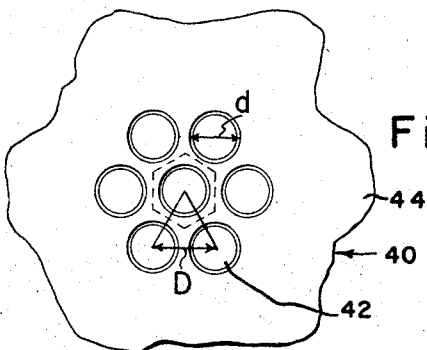


Fig. 5

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ABSTRACT OF THE DISCLOSURE

A truncated, conical type paper refiner is provided with plug fillings or shell linings in which the working face is pitted with a multiplicity of small diameter holes, the sum of the hole area being equal to, or greater than, the sum of the non-hole area and the ratio of the hole edge length to the area of the face associated with each hole comprises a predetermined ratio consisting a K factor of from about 3.6 to about 3.8.

This invention relates to paper stock engines of the type having a frusto-conical plug revolvable in a frusto-conical shell such as Jordan engines and "Claffin" engines. More particularly the invention relates to improved comminuting surfaces or "tackle" for such engines.

Such engines have opposed shell fillings and plug linings, each with irregularly surfaced comminuting members such as bars, knives, or the like, which provide, in addition to a shearing action, whereby fiber bundles are beaten apart or "refined," a cutting action. It has formerly been proposed to modify the meeting surfaces of these fillings or linings with hydration-producing holes wherein such holes cover an area not exceeding one-half of the entire surface. This proposal was embodied in U.S. Patent No. 1,583,771 to Bidwell of May 11, 1926, and has been successfully utilized in the art of paper making for many years. However, it has always been desirable to improve the performance of this type of apparatus both in respect to the uniform quality of product which could be obtained therefrom and with respect to the operating costs required by the apparatus.

Therefore, it is a principal object of the instant invention to provide an improved paper refiner of the Jordan or "Claffin" type.

It is a further object of the invention to provide apparatus that will be capable of processing an improved paper stock.

It is another object of the invention to provide apparatus that is capable of producing high quality paper stock at reduced operating costs.

It is still another object of the invention to provide a paper stock refiner with a comminuting surface having holes therein of such size and spacing that the refining action of the apparatus is improved.

Another object of the invention is to provide an improved process for making paper stock.

Still another object of the invention is to provide an improved replaceable comminution surface for paper refiners.

Applicant has substantially met the above objects with the surprising discovery that the performance of the type of comminuting surface previously known to the art as described in the Bidwell patent can be greatly improved by spacing and sizing the holes on a comminuting surface in such a way as to maintain an appropriate ratio of hole-edge perimeter to non-hole surface area of the working surface relatively constant but to increase the ratio of hole area to non-hole surface area to well in

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excess of 1:1, the limitation taught by the prior art. Thus, a particularly advantageous embodiment of the invention could utilize a stationary shell working surface have $\frac{3}{8}$ inch holes on a $\frac{15}{32}$ inch center-to-center spacing arrangement. Such a shell would have a ratio of hole area to non-hole surface area of about 1.4 to 1. However, shells having ratios of hole area to non-hole area of up to 2 and more are also useful and within the scope of the invention. Moreover, the advantages of the apparatus of the invention are particularly evident when the ratio of total hole edge length to associated non-hole surface area is between 3.6 and 3.8 most advantageously about 3.7. This term will be referred to henceforth as a K factor and is, where holes are laid out on equilateral triangles, a function of the hole diameter and distance between hole centers:

$$K = \frac{d}{1.1D^2 - d^2}$$

In this application and accompanying drawings, I have shown and described a preferred embodiment of my invention and have suggested various alternatives and modifications thereof, but it is to be understood that these are not intended to be exhaustive and that other changes and modifications can be made within the scope of the invention. These suggestions herein are selected and included for purposes of illustration in order that others skilled in the art will more fully understand the invention and the principles thereof and will be enabled to modify it and embody it in a variety of forms, each as may be best suited to the condition of a particular case.

FIGURE 1 is an elevational view, partially in section, of the refining section of a refining engine of the "Claffin" type.

FIGURE 2 is a plan view of a segment of a stationary hydrating element according to the invention.

FIGURE 3 is an enlarged, side view in half section, on line 3—3 of FIG. 4 of one of the hydrating segments of the invention.

FIGURE 4 is a section through line 4—4 of FIGURE 2.

FIGURE 5 is a fragmentary diagrammatic plan view showing the preferred diameter and spacing of the holes of the invention on a greatly enlarged scale.

Referring now to FIGURE 1, it is seen that refining apparatus 12 includes a truncated conical plug mounted on a shaft 14 journaled at each end in bearings 16 and 18. The outer shell 20, of apparatus 12, comprises a stock inlet 22 and a stock outlet 24. These outlets are connected by a conical flow path 26 through which pulp being refined is passed.

On the inner surface of shell 20 is a stationary filling 28 having a comminuting surface 29 thereon. Opposing the filling 28 is the plug lining 30 mounted on plug 32, which plug is, in turn, mounted on shaft 14.

Plug lining 30 is equipped with bars, or knives, 33 on the surface thereof, such as are known in the art to provide good refining action.

In operation, as will be understood by those skilled in the paper-manufacturing art, plug lining 30 is rotated at such speeds as to exert a high shear on the fibrous material carried between the shell and plug members 28 and 30 in flow path 26.

FIGURES 2 and 3 show a segment 40 of stationary shell filling 28. The filling 28 is assembled by mounting a series, such as sixteen, of segments 40 within shell 20. Each segment 40 is cast, in one piece, in castable metal, such as steel. A large number of holes 42, each $\frac{3}{8}$ " in diameter and centered $\frac{15}{32}$ " apart one from another, are cast into the smooth, comminuting, or working surface 44

of segment 40. The extremities 43 of each segment 40 are machined for fit into shell 20 as is known in the art.

FIGURE 4 shows an end view of segment 40 more clearly showing the concave shapes required for fitting of the arcuate segments 40 within shell 20. Also shown in FIGURE 4 are cross-sections of some of the holes 42 in comminuting surface 44. The holes shown are one inch in depth, and spaced uniformly about $\frac{3}{32}$ " apart. There are preferably about 700 to 800 holes 42 in each segment, but this, of course, depends on the size of the machine and number of segments required therefor.

It has been found that one of the most critical and significant factors responsible for good performance characteristics in pitted, or perforated, hydrating shell designs is the ratio of effective edge length to exposed surface area. Thus, as the hole size is increased, the distance between holes should be increased accordingly to maintain this critical ratio of edge to area.

As shown diagrammatically in FIGURE 5, the centres of the holes can be located at the apices of equilateral triangles with sides of length D. With this arrangement, the area associated with each hole is hexagonal in shape. The exposed surface area per hole (which is believed to accomplish the essential brushing of the fibres), can be defined as the area of the hexagon AH minus the area of the hole itself AO. Similarly the length of effective edge per hole (which is believed to accomplish the cutting or shearing of the fibres) can be defined as half the circumference projected on the plane of the axis, or simply diameter d.

Utilizing the dimensions of a particular known hydrating shell of the Bidwell type having drilled holes, for example $\frac{5}{32}$ " in diameter and $\frac{9}{32}$ " between hole centres, a constant K can be developed representing the ratio of edge to area, as follows:

Area of hexagon=AH=0.865D²;

Area of hole=AO=0.785d²;

Surface area associated with each hole=AH-AO;

Projected length of edge of each hole=d;

$$\text{Ratio of edge to area}=K=\frac{d}{.0865D^2-0.785d^2}$$

or when $d=\frac{5}{32}$ " and $D=\frac{9}{32}$ ", $K=3.5$

The K factor 3.5 may thus be used as a constant, with another d substituted and the equation solved for D, thereby maintaining the same ratio and the same performance characteristics.

It has therefore been found that the holes can be integrally cast in the shell segments, at a considerable saving in cost of manufacture, for example in the dimensions shown below, while achieving equal, or better performance.

	Hole Diameter	Distance Between Centers of Holes	K Factor
Drilled Hole Type.....	$\frac{5}{32}$	$\frac{9}{32}$	3.5
Cast Hole Type I.....	$\frac{5}{16}$	$\frac{13}{32}$	3.7
Cast Hole Type II.....	$\frac{5}{16}$	$\frac{15}{32}$	3.7
Cast Hole Type III.....	$\frac{7}{16}$	$\frac{17}{32}$	3.7

Apparatus made essentially according to the illustrated embodiment of the invention, having holes $\frac{3}{8}$ " in diameter, with $\frac{15}{32}$ between centres, was tested in a "Claffin" type refiner rated for handling one to three tons of stock per hour. In control tests, hydrating members, constructed according to the teachings of Bidwell and having holes $\frac{5}{32}$ inch in diameter with about $\frac{9}{32}$ " between centres were utilized on the outer comminution surface, i.e., the stationary shell filling of the same engine. Each tested apparatus had conventional bar-type members on the rotating surface.

Three comparisons of performance were made with the two machines using the following conditions:

Experiment 1.—The horsepower was maintained constant and the throughput was varied.

Experiment 2.—The throughput was maintained constant and the horsepower was varied.

Experiment 3.—Throughput and horsepower were both allowed to vary and the freeness of feedstock (called "furnish" in the art) was held constant.

In each instance, the performance of the apparatus of the instant invention was superior.

Especially noticeable was the improved minimum properties of paper made from the pulp refined in applicant's apparatus. Table I below shows a comparison of the values of paper quality as measured by various well-known control tests. The three papers A, B and C were carefully prepared in the same manner from identical stock excepting A was prepared from a non-refined control, B was prepared from paper refined in the above-mentioned Bidwell-type apparatus, and C was prepared in apparatus according to the instant invention.

RESULTS AS PERCENT OF A

Test	A B C C			
	Avg.	Min.	Max.	Min. Max.
Bursting Strength.....	100	112	160	128 160
Tear Strength.....	100	94	116	130 144
Tensile Strength.....	100	107	145	120 149
Fold Strength.....	100	100	400	200 600

It is abundantly clear that the apparatus of the instant invention performed extremely well especially in respect to the uniform good quality of the paper produced from the pulp refined therein as evidenced by the relatively high minimum strength characteristics and improved maximum strength characteristics.

Moreover, in Experiment 2, the instant apparatus operated at a considerable power saving while achieving the same output.

In Experiment 3, performance of the novel apparatus as measured by the fiber length retention and production of fewer fines was also clearly superior to the performance of the Bidwell-type apparatus.

The apparatus of the instant invention may be constructed of any of the materials known to the art to be advantageous in pulp-processing operations. For example, chrome-manganese or other stainless steels, mild steel, manganese, and the like.

The size of the holes may be varied somewhat. For example, holes of from $\frac{5}{16}$ inch to $\frac{7}{16}$ inch and larger may be used if they are spaced sufficiently far apart to permit a proper hole area: non-hole area ratio and desirable K factor. For example, to maintain the ratio shown for the illustrative embodiment described above, the following preferred table may be generally followed for engineering convenience:

Hole Diameter (inches)	Distance Between Centres of Holes (inches)	K factor	Approximate Hole: Non-Hole Area Ratio
$\frac{5}{16}$	$\frac{13}{32}$	3.7	1.15
$\frac{3}{8}$	$\frac{15}{32}$	3.7	1.39
$\frac{7}{16}$	$\frac{17}{32}$	3.7	1.61

Of course, it is understood that the rows of holes are staggered in a manner such as that suggested in the drawings.

The shape of the cast holes may be other than round, and, indeed, except for the added expense of forming such holes, in some applications other shapes, for example, polygons or ellipses, are often highly advantageous inasmuch as they increase the ratio of hole-edge to surface area and thus increase the cutting capacity of the apparatus. The depth of the holes may also vary. Normally they are rather deep in order to precompensate for expected wear. Usually they perform best when $\frac{1}{8}$ inch or more deep. Another variable factor is the shape of the hole. It is usually most convenient depending on the method of manufacture used, to have the holes taper slightly toward the bottom. When the taper is small, the

effect of tackle wear on change in hole dimension or refiner performance is not important.

It is also to be emphasized that the novel pitted comminution surfaces which have been described above may be utilized on either or both of the treatment surfaces in paper refining apparatus. For example, the plug may have a novel surface such as that described herein, or the inner surface of the shell may have such a surface, or both shell and plug may have novel surfaces according to the invention. Furthermore, the novel comminuting surface described herein may make up only a portion of the total surface of the stationary or rotating surfaces. Choice of which, or how many such surfaces will be embodied in the apparatus of the invention, is largely dependent on the type of refining action desired to be imparted to the pulp by the tackle during its passage through the refining apparatus.

What is claimed is:

1. In a stock engine of the type having a frusto-conical plug revolvable within a frusto-conical shell wherein said plug and said shell have comminuting members with irregular faces thereon,

the improvement comprising at least one said comminuting member having a plurality of holes in the face thereof but wherein the ratio of the sum cross-section of said holes to remaining face area is greater than 1 to 1, and the K factor of said comminuting member is from about 3.6 to about 3.8.

2. An engine as defined in claim 1, wherein said ratio of the sum cross-section of said holes to remaining face area is at least about 1.15, wherein said holes are equally-spaced one from another, and said K factor is from about 3.6 to 3.8.

3. An engine as defined in claim 2 wherein said holes are from about $\frac{5}{16}$ inch to $\frac{7}{16}$ inch in diameter, and said K factor is from about 3.6 to 3.8.

4. An engine as defined in claim 3 wherein one said comminuting surface comprises a series of bars thereon.

5. A replaceable structure adaptable for mounting on, and dismounting from, a stock engine of the type having a frusto-conical shell,

said structure comprising a comminuting surface having a plurality of small diameter holes, the ratio of total cross-sectional area of such holes to the remaining face area of said surface being greater than 1 to 1 and the K factor of said surface being about 3.7.

6. In a process for refining pulp stock, by subjecting said stock to a mechanical shearing action between two comminuting surfaces, the improvement comprising subjecting said stock to cutting and brushing action by at least one said surface which is provided with a plurality of small diameter holes, the sum cross-

sectional area of which holes is greater than the remaining area on said comminuting surface and the K factor of which surface is about 3.7, thereby subjecting said stock to excellent cutting and brushing action

while simultaneously minimizing the mechanical energy dissipated in heating said pulp stock.

7. A cast unitary filling segment for the shell of a truncated, conical refining engine, said segment comprising a generally triangular body of cast material having a concave, arcuate, relatively smooth, planar inner working face,

and a multiplicity of evenly spaced, cored holes cast in the material of said body, each generally normal to said face, each about three-eighths of an inch in diameter, and each converging slightly from said inner face toward the outer face of said body,

the total sectional area of all of said holes in said face being at least equal to the area of the remainder of said working face between said holes, and the K factor of said working face being from about 3.6 to about 3.8.

8. A stock refining engine of the type having opposed, relatively movable, stock treatment faces,

at least one said face comprising a plurality of identical detachable segments,

each said segment being a unitary body of cast metal having a smooth working face pitted with holes therein and extending over the entire face thereof, said holes being of predetermined diameter and spaced apart a predetermined distance in a uniform pattern, the cross-sectional area of the holes in each said segment being at least equal to the area of the remainder of the working face of said segment,

and said working face having a predetermined ratio of projected length of edge of each hole to surface area associated with each hole, said ratio constituting a K factor of about 3.7.

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