United States Patent

Pfeiffer

[15] **3,682,032**

[45] **Aug. 8, 1972**

[54] **SLITTER WITH SHARPNESS RETENTION CAPABILITY**

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[73] Assignee: **Beloit Corporation,** Beloit, Wis.

[22] Filed: **Dec. 16, 1969**

[21] Appl. No.: **885,553**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 835,407, June 23, 1969.

[52] **U.S. Cl.** **83/496,** 83/174, 83/501, 83/673, 83/676

[51] **Int. Cl.** **B26d 1/28**

[58] **Field of Search**.....83/96, 497, 503–508, 83/174, 673, 676

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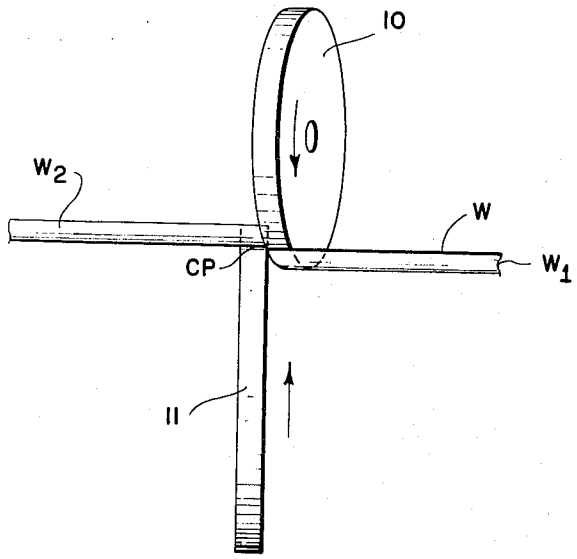
Primary Examiner—Frank T. Yost

Attorney—Larson, Taylor and Hinds

[57] **ABSTRACT**

A shear type slitter for a moving web of material, comprising a pair of disc-shaped slitter members which overlap slightly and are toed toward the oncoming sheet. Each member includes a thin lip which projects laterally from the disc and engages the lip of the other member to cut the web. The lips are so shaped that their intial sharpness is substantially maintained over a relatively long period of time, notwithstanding wear of material from the surface of the lips.

16 Claims, 17 Drawing Figures



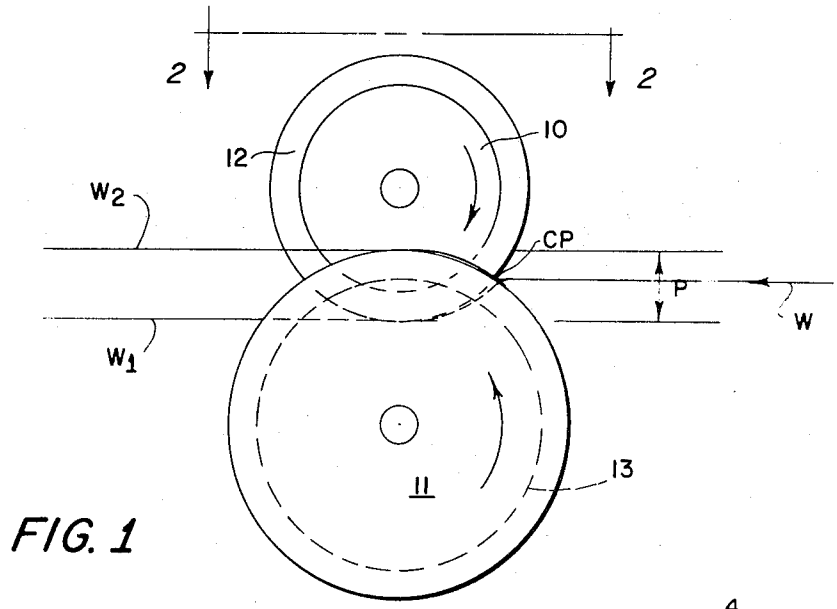
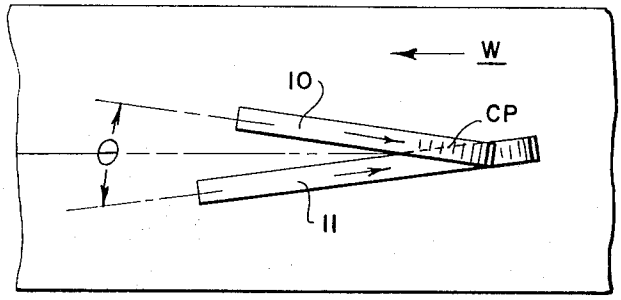


FIG. 1



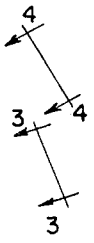


FIG. 2

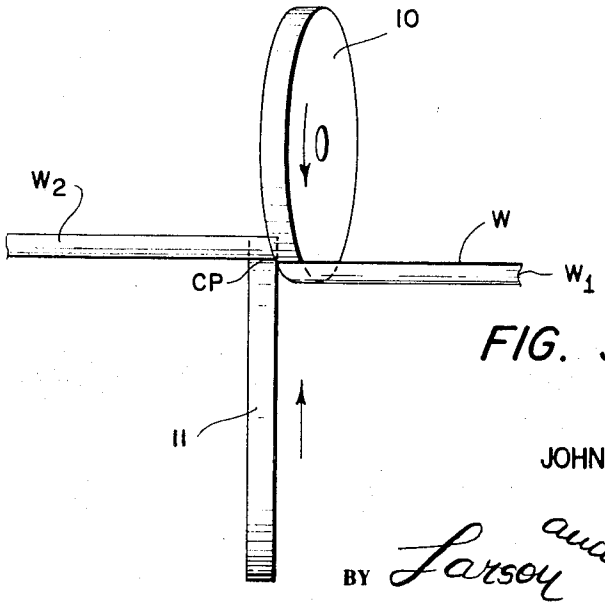


FIG. 3

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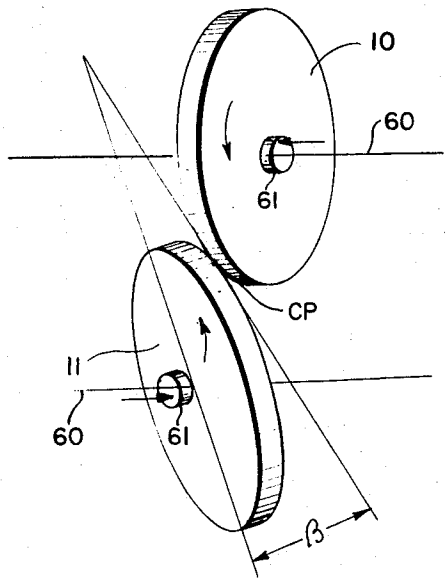


FIG. 4

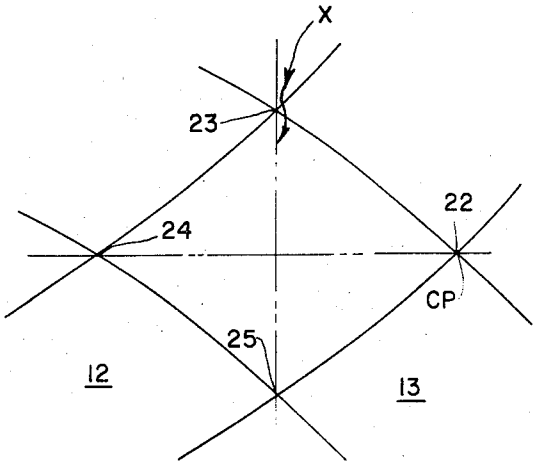


FIG. 7A

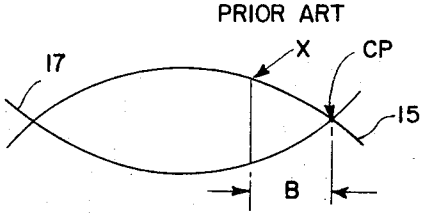


FIG. 5

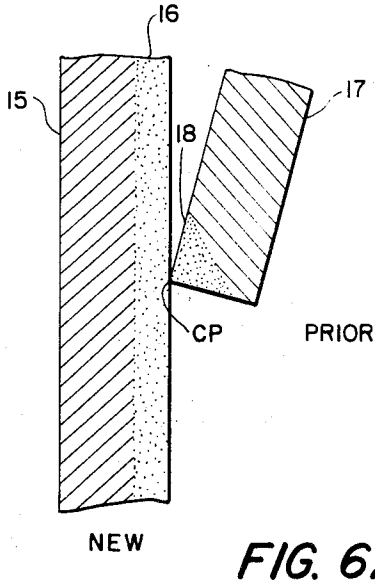


FIG. 6A

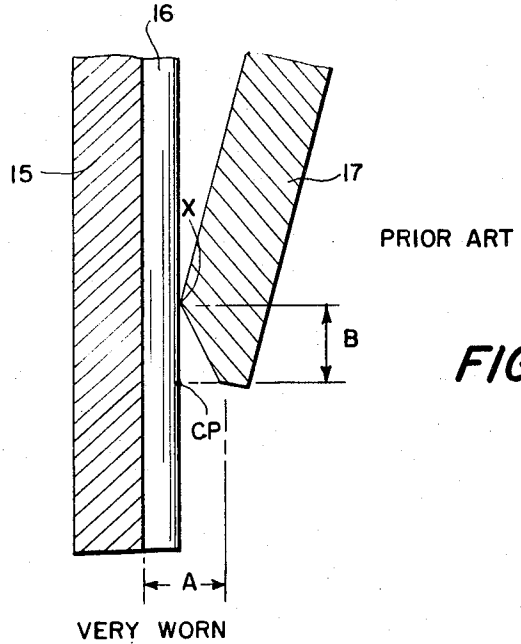


FIG. 6B

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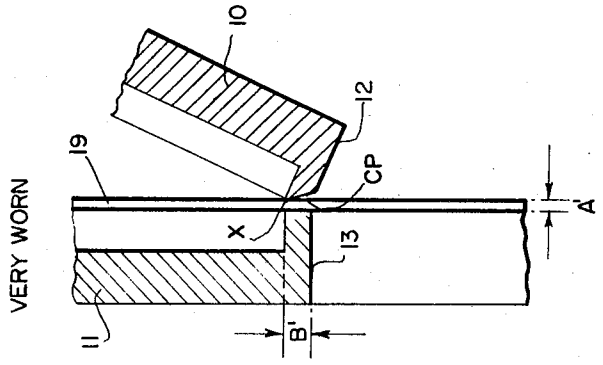


FIG. 8B

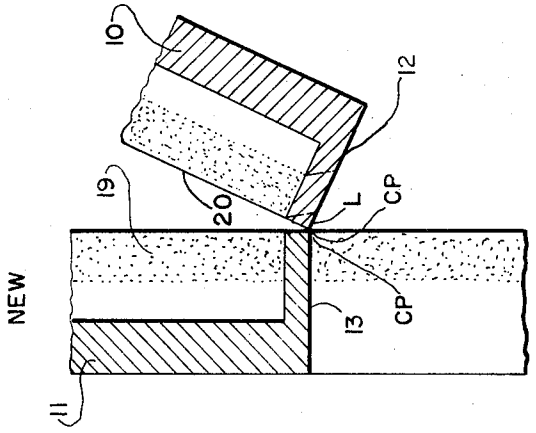


FIG. 8A

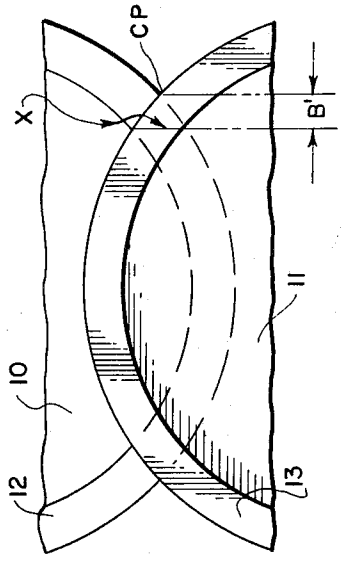


FIG. 7

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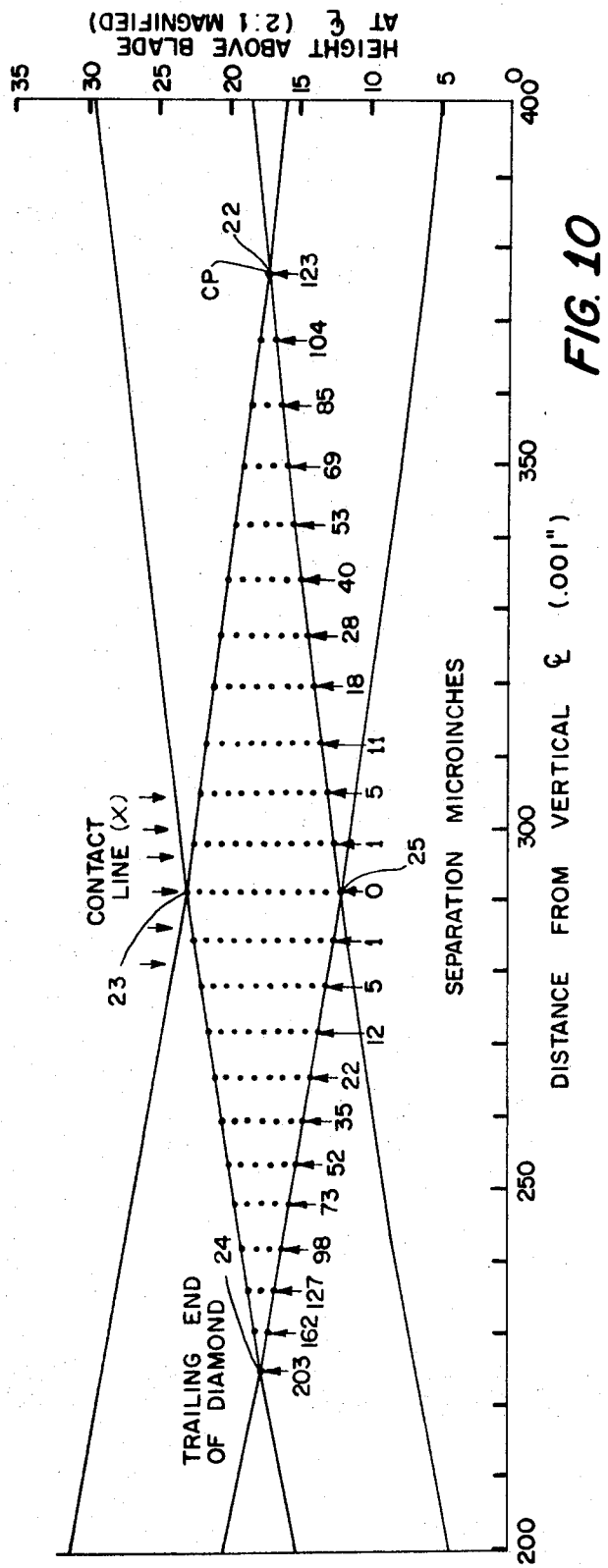


FIG. 10

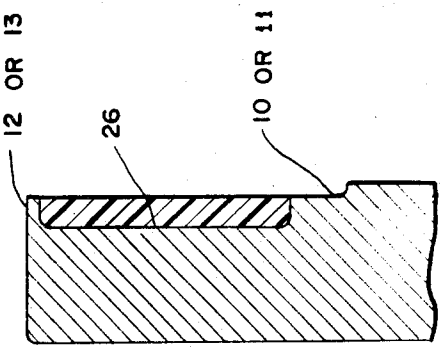


FIG. 9

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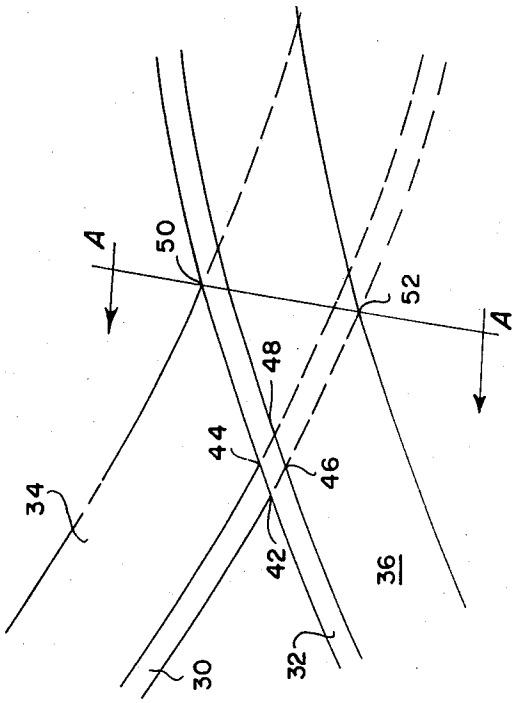


FIG. 12

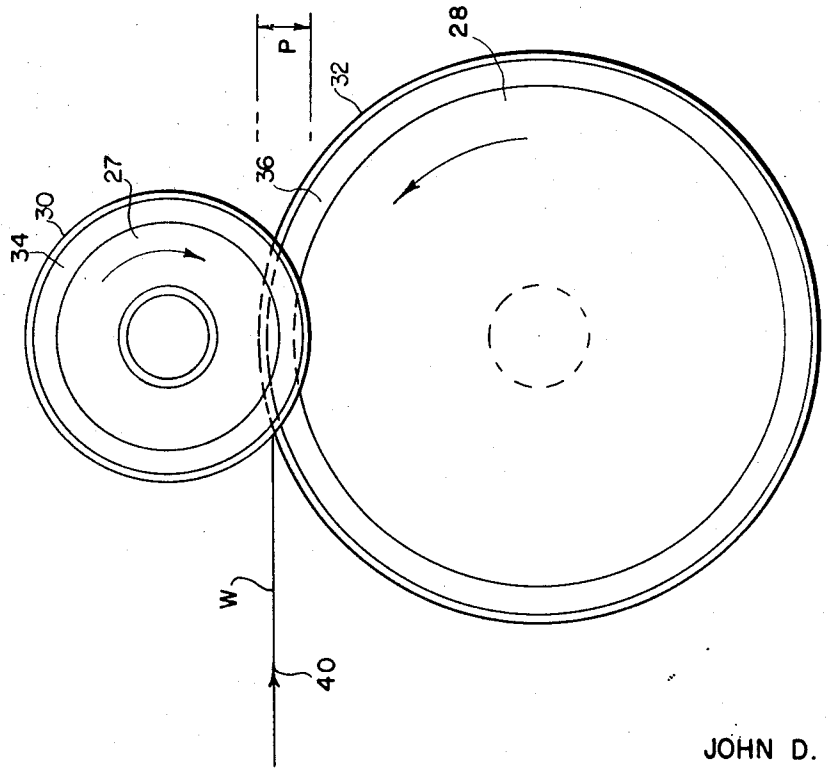


FIG. 11

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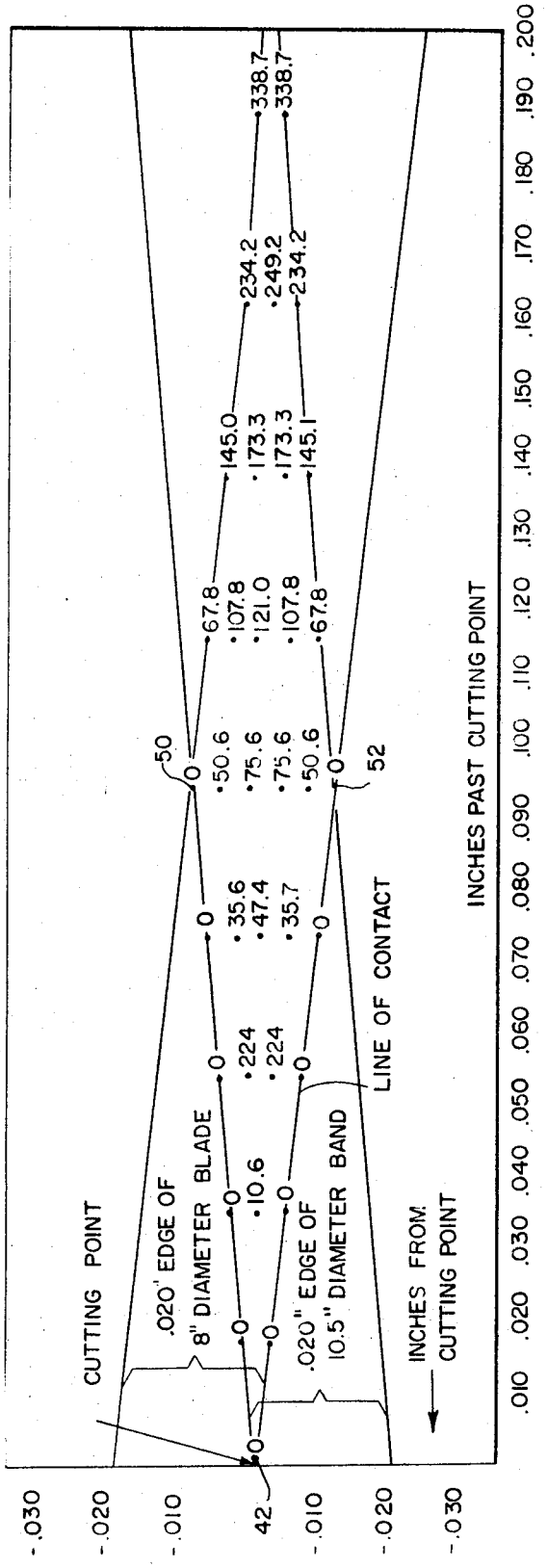


FIG. 14

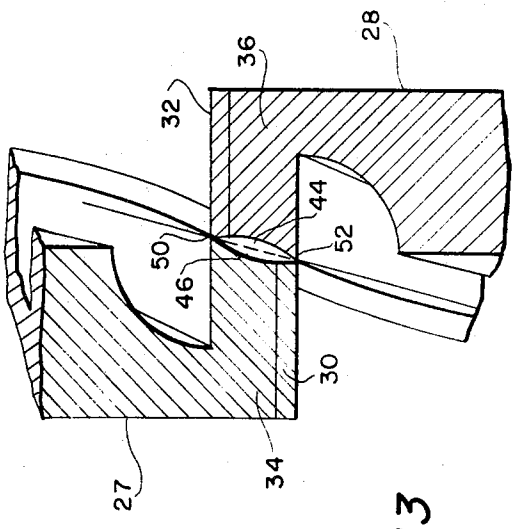


FIG. 13

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SLITTER WITH SHARPNESS RETENTION CAPABILITY

This is a continuation-in-part of my previous application Ser. No. 835,407, filed June 23, 1969.

BACKGROUND OF THE INVENTION

This invention relates to cutting apparatus for continuously slitting a traveling web or sheet of material and, more particularly, to a slitter which continuously maintains itself in a substantially sharpened condition while operating.

The specific application to which the preferred embodiment is directed is the continuous shearing of a traveling web of paper, although continuously slitting other web materials such as extruded plastic sheet, is contemplated and has been successfully practiced with this slitter. Also, the paper is frequently sheared as it is being rewound after leaving the paper machine. Typically, several slitters are mounted across the oncoming side of a winder stand. A recently wound roll of paper, which may be 60 inches in diameter and over 300 inches wide, is removed from the reel on the end of a paper machine and fed through the slitters and onto the winder as they are cut into various widths. This is a continuous process as paper machines are run around the clock. When slitter blades become dull, a large amount of paper dust is created by tearing and an undesirable ragged edge is formed on the cut paper. Replacement of dull blades, although necessary to avoid dust and ragged edges, is time consuming, bothersome and unprofitable. Any improvement in the useful life of a slitter has been greeted enthusiastically in the industry and of course a slitter wherein the slitting members had a long life and maintained the slitter as a unit in sharpened condition for the life of the blades would be most welcome. However, until now, this latter goal has not been achieved.

Prior slitting blade members have been advertised as self-honing while slitting, but after long periods of operation, the effectiveness of such a slitter in cutting a sheet decreased, notwithstanding the fact that the individual slitter blades (upper members) and bands (lower members) frequently remained razor sharp. In this type of device, the slitters generally comprised a blade mounted vertically over the band such that the edges of each overlapped in a vertical plane. The axes of rotation of the band and blade were in the same or parallel vertical planes and in parallel horizontal planes. The interaction of the blade on the band in the overlapping area caused the area of contact to increase rapidly as wear took place, and although the coacting edges were often sharp, it was discovered that pressure and wear of the band against the inner periphery of the blade eventually caused a gap to open between the innermost edge of the blade and band. This gap could get wide enough to prevent the slitting from cutting paper at all.

An important advancement in slitter design was disclosed and claimed in the Reeder Pat. Nos. 3,459,086 and 3,465,631, issued Aug. 5, 1969 and Sept. 9, 1969, respectively, which patents are commonly owned with this application. These patents were based on the discovery that (1) maximum sharpness might be achieved by establishing a point contact by toeing-in the blades about vertical axes and (2) that this "point" might be retained, and hence the life of the slitter

lengthened, if the flat radial engaging faces of the blades were replaced by relatively thin annular lips located on the sides of the members at the outer peripheries thereof such that the cutting action was constituted by the initial "point" engagement of the radial outermost edges of the two engaging lips. The developers of lip type web slitters, recognizing the theoretically perfect construction of an actual cutting "point," have strived to use the lip construction to retain this "point." For example, they have generally made the outer surface of at least one of the lips very hard in the belief that the point contact would be retained at the intersection between the slow wearing "thin" harder outer layer and the other member.

Although these previous patents represented a significant theoretical advancement in the art, in practice they did not work as well as anticipated. However, until now, the reasons explaining the concept of maintaining the point were not fully understood, and hence it was not possible to go forth to perfect and improve on this basic concept.

Thus, there existed a need for further advancements in the field of thin-lip web slitters to evaluate this type of slitter so that further advancement and perfection could be achieved.

SUMMARY OF THE INVENTION

Thus, it is a purpose of the present invention to provide a new and substantially improved lip type web slitter.

Contrary to the previous slitters, the present invention starts from the discovery that "point" contact of the two slitting members, although theoretically desirable, cannot be achieved in practice. Thus, another approach must be taken to arrive at the best practical slitter construction.

The reason why a "point" cut is the theoretically perfect solution is that it slits the paper without first tearing or otherwise dislodging or separating out any individual fibers of the paper. Perfect cutting through all fibers gives a perfectly clean cut, but separated fibers make up dust which is a major problem in the paper slitting industry and partially dislodged fibers show up as ragged edges. This same effect is observable on a larger scale by comparing a scissor cut paper edge with a ragged torn edge of the same paper. In practice, however, the point is not maintained and dullness follows, as evidenced by ragged edges and formation of dust.

Studies have now shown that dulling of a slitter assembly is due not only to the loss of keeness of the individual cutting members, but also to the shape which the components assume as they wear. The engaging edges, originally sharp corners, become conical in shape as they wear. As soon as the surfaces are worn on each cutting member, the contact must move back away from the initial cutting point and hence cutting takes place in a finite contact surface area rather than at a point. As the area of contact moves back away from the original cut point, the members separate from each other, that is they open up laterally at the location where there was initially point contact. For convenience, the location of the initial cut point will continue to be referred to as the "cut point." Thus, it is correct to say that as the wear continues, the cut point will open up. Further wear will move back the actual

contact area even more and the cut point will open up even more until it has opened up far enough for the components to lose their ability to shear.

When the wear has progressed back to a certain point, the paper entering the cutting zone will first be torn by the open spaced apart members at the cut point. This tearing will dislodge and separate fibers, thereby causing two ragged edges and dust. One of these ragged edges will be cut clean when it reaches the cutting or contact surface area, causing more dust, and the other will remain ragged. Finally, wear continues until the cut point is opened too much for shearing to occur. Trying to shear paper with the cut point laterally open too far is much the same as trying to operate a pair of scissors lefthanded. In both cases the ability to keep the theoretical cut point in contact is lost and clean shearing becomes impossible, because folding takes place well before the opening approaches the thickness of the sheet.

Thus, in contrast with previous approaches which have concentrated on maintaining a point contact wherever the two members happen to come together, the present invention recognizes that the best slitting is achieved by keeping the cut point opening as small as possible. Since cut opening is directly related to the distance which the actual cutting surface moves back from the original cut point, the thin lips are used and constructed to limit rearward movement of the contact surface area from the original cut point, even after considerable material has worn off of the thin lips.

Theoretically, the best results are attained with the thinnest possible lip. However, a lower level is reached beneath which the structural integrity of the lip is insufficient to stand the forces exerted thereon in operation. Moreover, it has now been discovered that optimum lip thickness is related to the distance of overlap of the two blades, this overlap commonly being referred to as the "penetration."If the lip thickness is too small for a given penetration, there will be too much turning force and drag exerted on the lips, thereby causing the paper to tear.

In a preferred embodiment of the invention, the lip is of a uniform hardness throughout its thickness in the radial direction. However, it is also possible to construct the lips with a given radial thickness having a very thin hardened outer layer. The two hardened layers would then act as the thinnest possible, and perhaps the best possible lips. However, at this time it is most difficult to produce slitter members having hardened layers on their lips such that the hardened layers will retain their structural integrity during operation of the slitting assembly.

When using the preferred embodiment which comprises a set of slitter members each having a thin lip of uniform hardness throughout its respective radial thicknesses, and assuming a penetration such that the entire thickness of the upper lip passes beneath the entire thickness of the lower lip, the overlap of the two lips, when viewed in elevation, will comprise two diamond-shaped areas. Since the two slitting members are toed-in relative to each other, contact will be made only at the forward diamond-shaped area, that is the area in the direction from which the web of paper is received. When viewed in elevation, the longer diagonal of the diamond is horizontal while the shorter diagonal of the diamond is substantially vertical. Initially the cutting point will be at the forward tip of the diamond. However, as the edges of the lips wear away, the area of actual contact will move back from the original cutting point to the short vertical diagonal of the diamond. Thus, the smaller the radial thickness of the lips, the smaller will be the diamond-shaped area. Consequently, for a smaller diamond, the rearward movement of the actual contact area will be less and hence the opening at the original cut point will be less.

When using hardened outer layers, the two hardened layers will be much thinner than the lips of uniform thickness and hence the diamond-shaped overlapping area formed by the two hardened layers will be very small. Consequently, the rearward migration from the original cutting point to the small diagonal of this small diamond will be very slight. Behind the small diamond-shaped area line contact will occur between each of the hardened layers and the relatively softer face of the other member beneath its hardened layer.

Thus, it is an object of this invention to provide a slitter capable of maintaining itself in a continuously sharpened condition to continuously cut a traveling web or material.

It is another object of this invention to provide a slitter which does not require the regular replacement of slitting members.

It is still another object of this invention to provide a slitter in which the maximum gap possible between the slitting members at the cut point is maintained as small as possible consistent with maintaining the structural integrity of the lips of the slitting members.

It is still another object of this invention to provide a basis for designing lip type slitter members wherein the lips are so constructed that the opening at the cut point of the lips and the rearward migration of the actual contact area from the original cut point are maintained as small as possible consistent with the structural requirements of the lip.

It is another object of this invention to provide a lip type slitter member in which the thickness of the lip is constructed in conjunction with the overlap of the slitting members such that the best possible balance is achieved between lip thickness and efficiency of operation.

These and other objects, features and advantages of the invention will be readily apparent from the detailed description to follow along with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

There follows a detailed description of preferred embodiments of the invention to be read together with the accompanying drawings, the description and the drawings being provided only for purposes of illustration.

FIG. 1 is a side elevational view of a pair of cooperating slitting members constructed in accordance with the features of the present invention.

FIG. 2 is a plan view taken in the direction of the line 2—2 of FIG. 1.

FIG. 3 is an end elevational view taken in the direction of the line 3—3 in FIG. 2.

FIG. 4 is an end elevational view similar to FIG. 3 and taken in the direction of the line 4—4 of FIG. 2 but

wherein the elements of FIG. 2 have been turned counterclockwise to reveal the plane passing between the two slitter members and contacting them only at a given point.

FIG. 5 illustrates the overlapping portion of prior art slitter members.

FIGS. 6A and 6B are views of prior art slitter members showing the new and very worn conditions, and taken in the plane of the incoming web of paper and looking downwardly.

FIG. 7 is an enlarged view of the overlapping portion of FIG. 1.

FIG. 7A is an enlarged view of a portion of FIG. 7.

FIGS. 8A and 8B illustrate new and very worn slitter blades constructed in accordance with the present invention and taken through the plane of the incoming web of material and looking downwardly.

FIG. 9 is a cross-sectional view of a portion of an actual slitting blade constructed in accordance with the features of the present invention and drawn to scale.

FIG. 10 is a graph illustrating the operation of the present invention.

FIG. 11 is a side elevational view of a slitting members constructed in accordance with an alternative embodiment of the invention.

FIG. 12 is an enlarged schematic view of a portion of FIG. 11.

FIG. 13 is a sectional view along line A—A of the intersection of the slitting members shown in FIG. 12.

FIG. 14 is a graph illustrating the operation of the alternative embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the figures, like elements represent like numerals throughout the several views.

FIGS. 1 through 4 illustrate in generally schematic form the relative positions of the slitter blade **10** and the slitter band **11** both with respect to each other and with respect to the traveling web W. The members **10** and **11** include thin lip portions **12** and **13**, respectively. The widths of the lips **12** and **13** are grossly exaggerated in FIG. 1 in order to illustrate the principles of the present invention. In an actual embodiment (as will be explained in greater detail below) the slitting members may be approximately eight to ten inches in diameter and the thickness of the lips **12** and **13** will be approximately ten to fifteenth thousandths of an inch. Moreover, the vertical overlap or "penetration" of the slitting members, which is designated by the letter P in FIG. 1, will normally be approximately thirty to sixty thousands of an inch.

Referring now to FIGS. 1 through 4, the slitting members **10** and **11** are turned about central axes passing therethrough in the direction of the arrows as shown in FIGS. 1 through 4. The slitting members are toed-in or canted relative to the direction of travel of the web W, the total angle formed between the two slitting members being the angle θ as shown in FIG. 2. With the two slitting members arranged as described above, and assuming that the sides of the outer edges of each of the two slitter members which face the other slitter member are perfectly squared off, then the two slitter members will contact at a single point which is shown in the figures CP to represent the cut point. FIG. 3 is a front elevational view of FIG. 2 and FIG. 4 is a front elevational view wherein the slitter members **10** and **11** have been turned counter-clockwise and tilted out of the plane of the paper about a horizontal axis passing through the point CP. As thus oriented, FIG. 4 will reveal a single plane tangent to the engaging circles of slitting members **10** and **11** at point CP. The angle formed by this plane tangent to the two contacting circles of members **10** and **11** and a vertical line passing through the axis of the slitter member **11** represents the wear angle β. Although the principles of operation of the invention will be described throughout with respect to exaggerated, schematic views, reference to FIG. 9 will illustrate one actual embodiment of the invention. FIG. 9 is a cross-section through either the slitter blade **10** or the slitter band **11** and the lip could be either the lip **12** on the blade **10** or the lip **13** on the band **11**. In this particular embodiment the overall thickness of the slitting member is 0.2 inches except at the outer periphery, that is in the vicinity of the lip **12** or **13**, the thickness is only 0.190 inches. This relief at the outer periphery of the slitting member will protect the lip in that it will render it less vulnerable to accidental breakage. Theoretically, of course, the two radial faces of the slitter member could be flat all the way out to the periphery and the lip could extend outwardly therefrom. In the present case the lip is formed by cutting into one radial face to form the annular recess **26**. Although this annular space could be left open, for stability and to avoid accidental breakage of the lip, it is preferable to fill this space with a relatively soft material such as plastic or the like. Obviously this plastic material plays no part in the operation of the invention itself. In the illustrated slitter member, the recess **26** may extend axially from the outermost edge of the lip 0.062 inches, thereby leaving a lip which projects outwardly from the bottom of this recess by 0.062 inches.

The principle of operation of the invention will now be explained with respect to FIGS. 5 through 8. FIG. 5 illustrates the overlapping portion of a prior art band **15** and a prior art blade **17**. The elements **15** and **17** are pure cylindrical discs, that is they comprise a pair of completely flat radial parallel faces. This drawing is equally applicable to prior art devices having very thick lip structures. Assuming that the elements **15** and **16** are tilted or toed-in with respect to each other, then when these elements are brand-new they will contact at a single point CP. This point CP is visible in FIG. 5 and also in FIG. 6A. In FIGS. 6A, which represents new elements contacting at a single point CP, the portions which will eventually wear are speckled and illustrated at **16** and **18**. When the portions **16** and **18** are viewed in cross-section, both appear as substantially triangular sections, as shown at **18**, thereby leaving both of the elements **15** and **17** in the form of truncated cones with beveled worn surfaces. FIG. 6B illustrates the position of the elements after the speckled portions have worn off of the elements **15** and **17**. Since this type of apparatus employs a means for urging the two members **15** and **17** together in the axial direction, after the speckled portions have worn off, the elements will now contact each other at a line X which is rearward of the original cut point CP by a distance B. Also, at the position of the original cut point CP, the elements **15** and **17** are now separated by the rather substantial opening A.

Studies have now revealed that it is the large opening A at the cut point CP and the large rearward migration B from CP to X which results in poor performance of the slitter, this poor performance being manifested by unacceptable formation of dust and unacceptably ragged edges.

FIGS. 7 and 8 illustrate how the same amount of wear as shown in FIGS. 5 and 6 (the axial distance of portion 18 of FIG. 6A) will not result in a dulled slitter when the slitter is made is accordance with the features of the present invention. FIG. 7 illustrates the overlapping portion of FIG. 1 and FIG. 7A is an enlarged portion of the forward diamond-shaped overlapping portion of FIG. 7. This diamond is formed by the forward cut point 22, a rear point 24 which is always open and points 23 and 25 at opposite ends of the short diagonal of the diamond.

Referring now to FIGS. 8A and 8B, in these figures the sitter members 10 and 11 include projecting lips 12 and 13. In FIG. 8A the new elements 10 and 11, and in particular the lips 12 and 13 contact at a single point CP. Speckled portions 19 and 20 represent the portion of lips 13 and 12 which will wear away. It will be noted that the axial distance of these speckled portions is the same as the axial distance of the speckled portions representing the wear in FIGS. 6A and 6B.

In the case of the present invention, the lips will wear back. As the portion L in FIG. 8A is being worn, the cut point will be moving back from point CP to the line X which is the small diagonal of the triangle in FIGS. 7 and 7A between the points 23 and 25. However, at this point, contrary to the prior art, further wear of the speckled portions 19 and 20 will cut completely through the lips 12 and 13 so that the two slitter members 10 and 11 will be urged towards each other but the contact point will migrate back from the original cut point CP no farther than the location of the small diagonal between points 23 and 25. Thus, as shown in FIG. 8B, after the members have worn back to an amount equal to portions 16 and 18 in FIGS. 6A and 6B, the opening A' at the cut point has remained much smaller than the opening A and the rearward migration B' has remained much smaller than the rearward migration B in FIG. 6B. Thus, having utilized the discovery of the present invention to reduce the opening at the cut point and the rearward migration of the contact point, there is provided a slitter assembly which, even after substantial wear, continues to operate as a sharp slitter. Because the lateral opening A' is small and the rearward migration B' is small, the slitter assembly as shown in FIG. 8B will continue to engage the individual fibers of the paper with a sufficiently positive force such that the individual fibers will not be torn, dislodged or separated from the paper and hence dust and ragged edges will still be minimized. Moreover, with the present invention, another problem of the prior art will be eliminated. In prior art devices such as shown in FIGS. 5 and 6, if wear causes the contact point X to move back to the line joining the two axes of rotation, the band and the blade would not slide relative to one another, as is necessary to produce the shearing action, but rather they would simply roll together. In contrast thereto, in the present invention since the actual contact point can migrate rearwardly no farther than the diagonal between points 23 and 25, there is no danger of the contact point moving rearwardly to the line joining the axes of the two slitter members whereat such rolling contact could occur.

It is contemplated that the slitter members 10 and 11 would be freely rotated on shafts such that they could be driven directly by the webs being slit. However, in the alternative, it is of course possible to drive the slitting members 10 and 11 by suitable motor means. The members 10 and 11 would be supported by suitable means known per se and shown schematically at 60 in FIG. 4 for supporting the members 10 and 11 for rotation about their axes; and suitable means such as is shown schematically at 61 would be provided for urging the members 10 and 11 towards each other.

In a preferred embodiment of the invention, the slitting members 10 and 11 will have outer lips 12 and 13 having a radial thickness of 0.011 inches, these lips having a hardness of Rockwell 53 to 58. This range represents the hardest materials which can be formed for a lip of this thickness consistent with the requirements that the lips be strong and uniform. In the preferred embodiment, the blade would be 8 inches in diameter and the band 8.5 inches. The total toe-in angle would be 1.0° and the total penetration P would be 0.0342 inches.

The above dimensions of the preferred embodiment are by no means limiting, but on the other hand, they are not completely arbitrary. Rather, they result from certain relationships which may be best illustrated by the following tables. In both tables the toe-in angle θ is 1°. In Table I the blade is 8.0 inches in diameter and the band 8.5 inches in diameter. In Table II the blade is 8.0 inches in diameter and the band 10.5 inches in diameter. When considering this table it should be kept in mind that paper fibers range in width from 78 microinches to 780 microinches.

TABLE I

Penetration (P) Thousand of an inch	Lip Thickness Thousands of an Inch	Cut Point Opening (A) Microinches	Wear Angle (B) Degrees
25	5	34.8	7.14
25	10	183.19	8.23
25	11	236.39	8.51
25	12	301.27	8.83
25	20	1909.53	14.05
34.2	5	20.38	5.92
34.2	10	97.81	6.5
34.2	11	123.22	6.64
34.2	12	152.91	6.78
34.2	20	640.66	8.45
45	5	12.96	5.07
45	10	59.08	5.41
45	11	73.52	5.49
45	12	90.05	5.57
45	20	325.2	6.39
62	5	7.73	4.25
62	10	33.86	4.45
62	11	41.76	4.49
62	12	50.67	4.54
62	20	166.49	4.94

TABLE II

Penetration (P) Thousands of An Inch	Lip Thickness Thousands of An Inch	Cut Point Opening (A) Microinches	Wear Angle (B) Degrees
25	5	36.54	7.5
25	10	192.34	8.64
25	11	248.2	8.93
25	12	316.31	9.26

25	20	2004.73	14.72
34.2	5	21.4	6.22
34.2	10	102.71	6.82
34.2	11	129.39	6.97
34.2	12	160.56	7.12
34.2	20	672.7	8.87
45	5	13.61	5.32
45	10	62.04	5.68
45	11	77.21	5.77
45	12	94.57	5.85
45	20	341.51	6.71
62	5	8.13	4.47
62	10	35.57	4.67
62	11	43.87	4.72
62	12	53.22	4.76
62	20	174.89	5.19

As explained earlier, it is ideal to keep the cut point opening A to a minimum. As is evident from the chart, the higher the penetration, the less will be the cut point opening. In addition, it can be seen that the smaller lip thickness will also result in a smaller cut point opening. Thus, following the chart one might theoretically select a penetration of sixty-two thousandths of an inch with a lip thickness of five thousandths of an inch thereby resulting in a cut point opening of 7.73 microinches. However, in practice such an arrangement would be totally unacceptable. In practice, a lip which is too thin with respect to the penetration, and considering the diameters of the blades, would suffer from several disadvantages. First, it would wear down in the axial direction entirely too fast. Secondly, the geometry of a very thin lip with respect to a high penetration would result in tearing of the paper. Also, this geometry is such that the force necessary to turn the blade and the band would be too great, that is the torque drag on the elements would be too great.

Tests with blades of various dimensions have shown that in practice the best conditions, that is the best balance of cut point opening, speed of wear of the lip and smooth engagement of the elements **12** and **13** is achieved when the lip thickness is approximately one-third of the penetration. In addition, a correct balance must be struck between penetration and the outer diameter of the slitter members. For example, if the penetration is too great, then the diamond-shaped area of FIG. 7A will tend to become "square." That is the diagonal **23–25** will become larger and the diagonal **22–24** will become smaller. As a result, the contact point will move from the cut point to the line X much more quickly and both wear and torque drag will be increased. On the other hand, if the penetration is too small, the diamond-shaped area of FIG. 7A will become elongated. That is, the diagonal **23–25** will become short and the diagonal **22–24** will become longer. This will increase the magnitude of the rearward migration B′ from point **22** to the line X, thereby causing a larger opening A′ at the cut point **22**. Thus, if much smaller bands and blades, for example 3 to 5 inches in diameter, or much larger blades and bands, for example 15 to 20 inches in diameter are used, then the figures for lip thickness and penetration must be modified accordingly in accordance with the principles set forth above.

Other disadvantages of excess penetration include disruption of sheet flow and unacceptable scrubbing. Disruption of sheet flow means that the two slit portions W_1 and W_2 (see FIGS. 1 through 3) will rise and fall too suddenly thereby exerting an undesirable force on the paper web as it moves through the slitter. Scrubbing refers to the radial sliding of the two slitter members against each other. Of course some scrubbing is necessary to shearing. However, too much will cause excess wear.

Thus, it will be apparent that many relationships in the Tables I and II are not actually practical. The preferred arrangement in Table I would appear to be the penetration of 34.2 thousandths with a lip thickness of eleven thousandths giving a cut point of 123.22 microinches. Since this opening is close to the lower end of the range of sizes of paper fibers, it has worked quite satisfactory in practice.

For the larger slitter members of Table II, the preferred dimension appears to be the penetration of sixty-two thousandths with a lip thickness of twenty thousandths giving a cut point opening of 174.89 microinches.

FIG. **10** is a graphical representation of FIG. 7A for the said preferred conditions of Table I using an 8 inch blade and an 8.5 inch band. The figures on the chart give the openings between points **22** and **24** in microinches when contact has worn back to the line X between points **23** and **25**.

By way of summary, it is believed that optimum conditions are obtained when using a lip thickness of between ten to fifteen thousandths of an inch. However, this is applicable primarily when using 8 and 8½ inch slitting members for which a penetration of thirty-four thousandths is believed to be optimum. The figures must be adjusted upwardly or downwardly for larger or smaller slitter member diameters.

FIGS. **11** through **14** illustrate another embodiment of the invention wherein an attempt is made to produce a much thinner lip than could normally be produced by a lip of uniform hardness. This is accomplished by forming a hardened layer of approximately two to four thousandths of an inch onto the outer surface of the lip. Referring to the figures, the slitter blade **27** has formed thereon a lip having a hardened outer portion **30** and a softer inner portion **34**. The slitter band **28** has a lip formed thereon having a hardened outer layer **32** and a softer inner layer **36**.

As shown in FIG. **12**, the two thin layers **30** and **32** form a very small diamond-shaped overlapping portion having a small diagonal **44–46** and a large diagonal **42–48**. In theory, the contact surface will move back from original cut point **42** only to the line **44–46**. Meanwhile, behind this small triangle the two layers **30** and **32** will wear away the softer portions **36** and **34**, respectively, back to the points **50** and **52** which are on opposite sides of the small diagonal of the larger triangle formed by the total lip portions. This wear of the hard layers **30** and **32** against the softer portions **36** and **34** causes a concave profile as best shown in FIG. **13**.

The outer peripheral edge surfaces **30**, **32** are surface hardened as by nitriding, to make them highly wear resistant.

The preferred dimensions of the various surfaces of FIGS. **11** through **13** are: the depth of surface hardened slitter edge surfaces **30**, **32** is 0.004 inch although it could reasonably range from about 0.002 to about 0.015 inch; face surfaces **34**, **36** are 0.020 inch wide, but could range between about 0.010 and about 0.025 inch wide. The axial thickness of the slitting members, including the width of outer slitter surfaces **30**, **32**, is 0.25 inch and the depth of the recessed portion radial

inward of the lip is up to one-half to three-fourths of this thickness. The total depth of penetration is 0.020 to 0.062 inches. This ensures the location of the contact point as always being forwardly of the line joining the axes of rotation in the direction of the oncoming sheet which in turn ensures relative motion and the elimination of rolling contact between contacting surfaces.

For slitting members dimensioned as above, a toe-in angle of 0.5° for each slitting member **27,28** with respect to the direction of web travel is preferred and combined to form a shear angle of 1.0° between the inner sides of the slitting members. However, in certain applications, such as edge trimming, the relative toe-in in kept at 1.0° while the whole assembly is turned as far as an additional ± 1.5° relative to the direction of web travel. This is done to produce a cross-machine directed tangential force to hold the sheet taunt at the edges and eliminate wrinkles.

FIG. **12** shows the essentially diamond-shaped intersection of face surfaces **34, 36**. Cutting point **42** is at the oncoming point of the intersection and points **50, 52** designate the upper and lower intersection points, respectively. The intersection point on the offgoing side is designated **54** although there is no contact at this point as explained later. For the preferred dimensions of 0.020 inch face surface width and radii of 4.0 and 5.25 inches for the slitting members, the approximate area of the diamond-shaped intersection is 0.00215 square inches. A small axial force urging the slitting members together will produce a relatively large pressure at the area of contact even assuming there is contact over the entire area of intersection which is not the case as explained later.

Referring to FIG. **12**, the thin wear resistant surfaces **30,32** intersect in a diamond-shaped area similar to, though very much smaller than, the intersection of face surfaces **34, 36**. As viewed axially in FIG. **12**, the actual initial point of contact, after the slitting members have been worn in, is a very short, approximately vertical, line **44–46** which connects two opposite points of the diamond-shaped area formed by intersecting outer edges **30, 32**. Intersection point **44** is formed between the innermost extension of wear resistant surface **30** on the blade and the outermost extension of wear resistant surface **32** on the band. Intersection point **46** is formed between the respective outermost and innermost extensions of the same surfaces. The remaining point **48** of this diamond designates the intersection of the innermost extensions of wear resistant surfaces **30,32**.

Due to the toe-in of each slitting member **27, 28** the radially innermost part of both wear resistant surfaces **30, 32** and face surfaces **34, 36** are worn away along a curved path extending radially inwardly from peripheral edges **30, 32** and axially away from the front **42** under the effect of the hard edges of surfaces **30, 32** eroding the relatively softer metal of face surfaces **34, 36**. This is shown in FIG. **13** which is a sectional view A—A taken through line **50–52** in FIG. **12**.

As the slitter members rotate toward one another, contact is maintained between edge surfaces **30, 32** along line **44–46**. As each wear resistant surface **30,32** continues to move inwardly past the other and onto the face surface of the other member, it wears away part of the material on each face surface **34, 36** along a slightly curved path (FIG. **13**).

The radially inner side of each face surface **34, 36** extends farther away from the corresponding peripheral slitter edge surface **30,32** of the other member due to the toe-in angle position of each slitter member away from a line along the direction of web travel by the arrows **40**. Accordingly, wear contact along each face surface **34,36** extends from points **44** and **46**, at the boundary between the wear resistant surfaces **30, 32** and the face surfaces, inwardly to points **50, 52** at the boundary between the inner face surfaces and the recessed portions. Since each slitter member **10, 12** diverges rearwardly from the contact point, the area of intersection from the hard surface **30** of one member to the face surface **36** of the other tapers to essentially line contact along line **46–52** as the face surface of the lower slitter member diverges away from the slitter edge surface **30** of the other member. Similarly, the hard surface **32** of the bottom member intersects with the face surface **34** of the top member and the area of intersection tapers to essentially line contact along line **44–50** as the face surface **34** of the upper slitter member diverges away from the hard surface **32** of the bottom member. The slitter edge surfaces **30,32** rotating radially inwardly through face surfaces **34,36** in their canted position forms the inwardly concave profile on both face surfaces.

The curved contacting surfaces **30, 32, 34, 36** and the diverging positioning of the slitter members cooperate to form a hollowed gap extending axially (perpendicular to direction **40** of web travel) between overlapping portions of the wear resistant and face surfaces rearwardly in the direction of web travel **40** from point **48** to line **50–52**. No contact exists beyond line **50–52** due to divergence of the slitting members.

Using parameters of 8 and 10.5 inches outside diameters of the blade and band members, respectively, 0.004 inch wear resistant surface thickness, 0.020 inch face surface, radial depth penetration of 0.062 inch and a toe-in angle of 0.5° for each slitter member, the gap between surfaces, as measured axially between slitting members and perpendicular to the direction **40** of web travel,has been calculated in terms of microinches and the values are shown in FIG. **14** at equally spaced points along the sides of the diamond-shaped area of intersection.

For the given parameters, the axial gap at the extreme outer overlapping point **42** of wear resistant surfaces **30,32** is 0.000005 inches (5 microinches) which is considerably smaller than the range of widths of single paper fibers which generally fall between about 78 and 780 microinches. Therefore, the cutting point, even though it is technically a gap and not a point a contact, cannot produce dust particles during the slitting operation which are larger than the width of a single paper fiber. Since the fibers are cut and are not pulled apart at the cutting point, the quantity of dust produced is minimized.

The operation of the embodiment of FIGS. **11** through **14** is as follows. As the beginning of operation of two new slitting members, the face surfaces and plane of the hardened wear resistant surface are perpendicular to the axis of rotation of each member. As the slitting members are urged together by some suitable loading means, such as an air diaphram, and rotated, either by the web or by a motor, the extreme outermost edges of wear resistant surfaces **30,32** make

point contact at 42. The web is generally supported and moved through the slitter by suitable means such as guide and drive rolls (not shown) on each side of the slitting members at a level whereby it is fed horizontally directly into the first point of intersection 42. After a period of time, the edges of surfaces 30, 32 wear into each other and a small gap forms at 42. As explained above, this gap is not detrimental to the slitting process and never widens to be greater than that desired according to the parameters of toe-in angles, wear resistant surface depth and diameter of the slitting members. A total toe-in angle of 0.7° for both slitting members has given satisfactory results with the other parameters held constant. Making the wear resistant surfaces 30, 32 thinner, such as 0.002 inch, will result in a smaller gap at point 42 if the other parameters remain constant. Contact is maintained along the line 44–46 (about 0.004 inch long in the preferred embodiment) and line contact diverges outwardly and rearwardly therefrom (FIG. 12). When the contact point has been established by wear along 44–46, a plane extends between the contact points of the inner face surfaces and wear resistant surface edge of the two slitter members, points 50 and 52 in FIG. 12. This plane is tangent to both slitting members at the point of contact and forms an angle with the plane of the inner surface of both the upper and lower slitting members. This angle is designated the wear angle with respect to whichever slitting member is taken as a reference. The wear angle has been found to be directly proportional to the toe-in angle and inversely proportional to the penetration. For a shear angle of 1.0° and penetration of sixty-two thousandths, the wear angle has been found to be about 5.2°.

The invention has been described in detail with particular reference to the preferred embodiment, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention as described hereinbefore.

I claim:

1. A slitter assembly for slitting a traveling web of material, comprising, a rotatable slitter band having an annular slitting lip of a predetermined radial thickness, the circumferential and one radial surface of said band lip forming a sharp corner which extends in a circle about the axis of said band, a rotating slitter blade adjacent the band such that the band and the blade overlap a predetermined amount along a line connecting the centers of the band and blade, the blade also having a lip of predetermined radial thickness, the thickness of each lip being approximately one-third the distance of said overlap along said line connecting the centers of the band and blade, the circumferential and one radial surface of said blade lip forming a sharp corner which extends in a circle about the axis of said blade, the approach side of the band and blade being tilted inwardly toward each other such that the two said sharp corners intersect each other at substantially a point which is on the web approach side of the slitter assembly, the arrangement being such that when the lips wear inwardly from the sharp corners in an axial direction, the lips will engage along a line located rearward of the location of the original said point, wherein the thickness of said lip determines the distance, in the direction of travel of the web, between the said original point and the said line, and wherein said lip thickness also determines the upper limit of lateral separation between the two lips at the location of the original said point after wear has taken place.

2. A slitter assembly according to claim 1, wherein the diameter of the band and blade are 8.0 inches and 8.5 inches, respectively, and wherein the said distance of overlap is approximately 0.034 inches and the thickness of each lip is approximately 0.011 inches.

3. A slitter assembly according to claim 1, wherein the diameter of the blade and band are approximately 8.0 inches and 10.5 inches, respectively, and wherein the said distance of overlap is approximately 0.062 inches and the thickness of each lip is approximately 0.020 inches.

4. A slitter assembly according to claim 1, wherein at least one of said blade or band is disc-shaped and the said lip thereof is bounded on its outer side by the outer peripheral surface of the disc and wherein said lip is bounded on its radial inner side by an annular recessed portion formed in the radial face.

5. A slitter assembly according to claim 4, including a plastic filler material in said recessed portion.

6. A slitter assembly for slitting a traveling web of material, comprising, a rotatable slitter band having an annular slitting lip of a predetermined radial thickness, the circumferential and one radial surface of said band lip forming a sharp corner which extends in a circle about the axis of said band, a rotating slitter blade adjacent the band such that the band and the blade overlap slightly along a line connecting the centers of the band and blade, the blade also having a lip of predetermined radial thickness, the circumferential and one radial surface of said blade lip forming a sharp corner which extends in a circle about the axis of said blade, the approach side of the band and blade being tilted inwardly toward each other such that the two said sharp corners intersect each other at substantially a point which is on the web approach side of the slitter assembly, the arrangement being such that when the lips wear inwardly from the sharp corners in an axial direction, the lips will engage along a line located rearward of the location of the original said point, wherein the thickness of said lip determines the distance, in the direction of travel of the web, between the said original point and the said line, and wherein said lip thickness also determines the upper limit of lateral separation between the two lips at the location of the original said point after wear has taken place, and wherein each lip comprises a radial inner portion of a first hardness and an outer layer of much greater hardness, the outer layer being approximately 0.002 inches to about 0.015 inches and the inner portion being approximately 0.015 inches to 0.025 inches.

7. A slitter assembly for slitting a traveling web of material, comprising, a rotatable slitter band having an annular slitting lip of a predetermined radial thickness, the circumferential and one radial surface of said band lip forming a sharp corner which extends in a circle about the axis of said band, a rotating slitter blade adjacent the band such that the band and the blade overlap slightly along a line connecting the centers of the band the blade, the blade also having a lip of predetermined radial thickness, the circumferential and one radial surface of said blade lip forming a sharp corner

which extends in a circle about the axis of said blade, the approach side of the band and blade being tilted inwardly toward each other such that the two said sharp corners intersect each other at substantially a point which is on the web approach side of the slitter assembly, the arrangement being such that when the lips wear inwardly from the sharp corners in an axial direction, the lips will engage along a line located rearward of the location of the original said point, wherein the thickness of said lip determines the distance, in the direction of travel of the web, between the said original point and the said line, and wherein said lip thickness also determines the upper limit of lateral separation between the two lips at the location of the original said point after wear has taken place, and wherein the radial thickness of each said lip is between 0.010 inches and 0.015 inches.

8. A slitter assembly according to claim **7**, wherein the lip extends inwardly from said sharp corner in the axial direction for approximately 0.062 inches.

9. A slitter assembly according to claim **8**, wherein the radial face of each disc opposite from that face having the lip formed thereon is generally flat, and wherein the said sharp corner of the lip is spaced axially from said flat face less than a central part of the disc.

10. A slitter assembly according to claim **7**, wherein the toe-in angle between the blade and the band is between 0.7° and 1.0°.

11. The slitter assembly of claim **7**, wherein each lip is of substantially uniform hardness throughout its radial thickness.

12. Apparatus for slitting a traveling web comprising: a blade member and a band member, each having an axis of rotation with a concentrically circular outer portion thereabout, a peripheral hardened slitter edge on said outer portion, a face surface extending radially inwardly a predetermined distance from said slitter edge toward said axis of rotation; said axis being in parallel horizontal planes, and offset from one another in vertical planes at an included angle, with at least one of said blade and band members being offset with the respect to the direction of web travel so that at least one of said blade and band members intercepts said web at a small toe-in angle; said blade is positioned with its axis of rotation vertically above the axis of said band a distance such that the respective face surfaces overlap a distance at least as great as their combined radial extension; pressure means supporting said blade and band members about their axes of rotation and urging them together on the side toward said oncoming web so that point contact is maintained at the intersection of said hardened edges and line contact extending from said point contact is maintained between each said hardened edge and the corresponding face surface on the other member.

13. Apparatus as set forth in claim **12**, wherein: said included angle is such that when said hardened slitter edges are in the range of from about 0.002 to about 0.015 inches, a gap of less than about 75 microinches opens on the oncoming side of the slitting members when the hardened edges are worn.

14. Apparatus as set forth in claim **12**, wherein: said included toe-in angle between said blade and band members is between from about 0.7° to about 1.0°.

15. Apparatus as set forth in claim **12**, wherein: said slitter edges on said blade and band members are each of substantially equal hardness: said hardened edges are more wear resistant than said face surfaces of said blade and band members.

16. Apparatus as set forth in claim **15**, wherein: said slitter edge of said blade and band members are hardened to a depth of from about 0.002 to about 0.015 inches.

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