Aug. 10, 1965 E. KELLER 3,199,575

OSCILLATORY ROTOR BLADE FOR TREATMENT OF FLUENT MATERIAL IN THIN LAYERS

Filed Oct. 31, 1962 3 Sheets-Sheet 1

Fig. 1

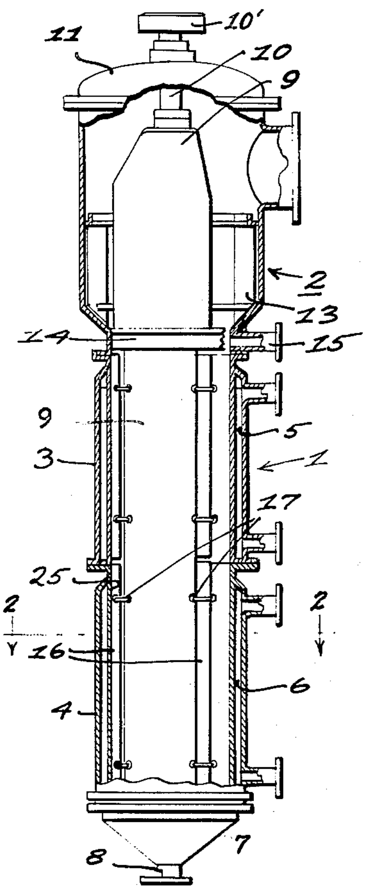
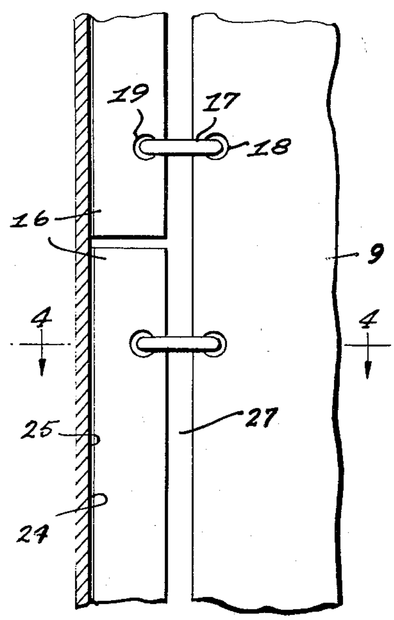


Fig. 3



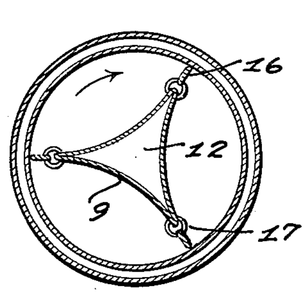


Fig. 2

Fig. 4

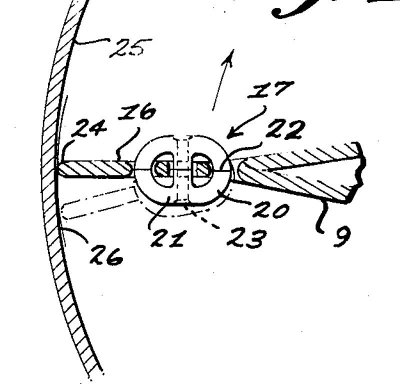


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Fig. 5

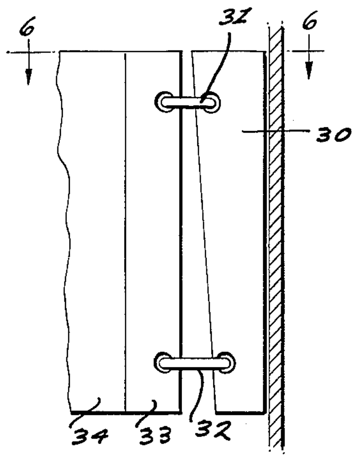

Fig. 7

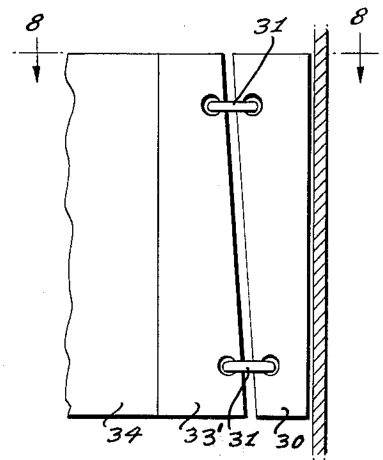

Fig. 6

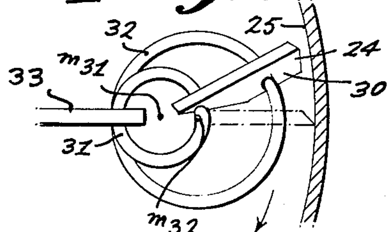

Fig. 8

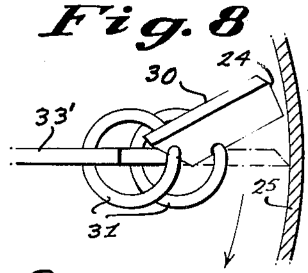

Fig. 9

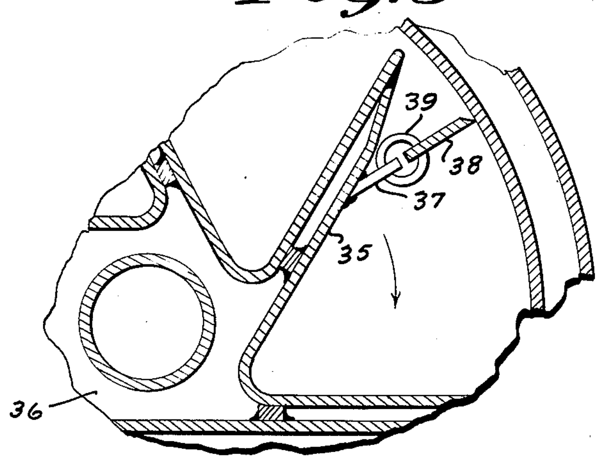

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Fig. 10

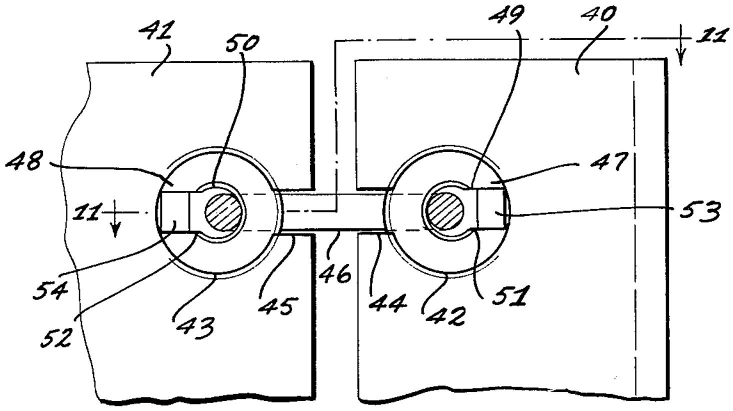


Fig. 11

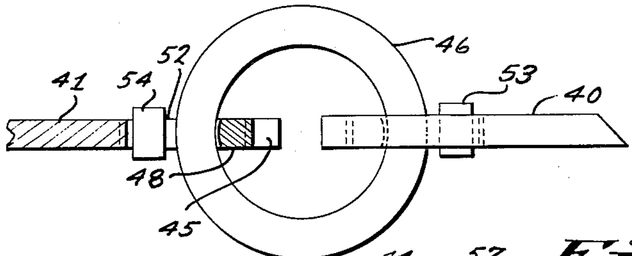
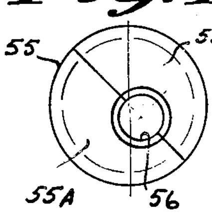


Fig. 12



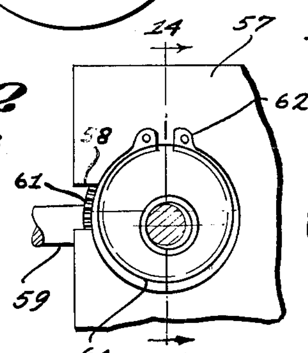


Fig. 14

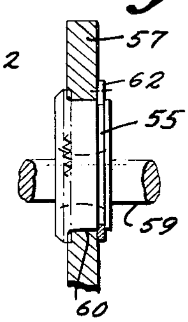


Fig. 13

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United States Patent Office

3,199,575
Patented Aug. 10, 1965

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OSCILLATORY ROTOR BLADE FOR TREATMENT OF FLUENT MATERIAL IN THIN LAYERS

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Filed Oct. 31, 1962, Ser. No. 234,505
Claims priority, application Germany, Nov. 2, 1961, L 40,371; Switzerland, May 24, 1962, 6,301/62
8 Claims. (Cl. 159—6)

This invention relates to apparatus for treating fluent materials, such as liquids, in thin layers or films, and in particular to apparatus of this sort adapted for evaporation of liquids from thin layers. The present invention provides an improved means for forming or spreading a thin layer of film of the fluent material being treated, and constitutes an advantageous elaboration of a schematic prototype disclosure included in copending application Serial No. 151,671, filed November 13, 1961 of which this application is a continuation-in-part.

Thin layer apparatus, especially the thin layer evaporator, is in common use today throughout the process industries. The principle of operation is characterized by the spreading of the liquid or other fluent material to be treated in a thin layer or film over a cooled or heated surface by means of a rotor structure.

The advantage of such apparatus, as compared with conventional equipment, is that heat and mass transfer is performed rapidly under uniform and easily controlled conditions, and in a continuous manner without harmful hydrostatic pressure conditions and with good mixing of the liquid.

Experience and numerous experimental investigations have shown that the performance of thin layer apparatus especially the heat transfer between the liquid and the heated or cooled surface, depends mainly on how the liquid layer is made by the rotor structure. The rotor structures heretofore proposed by the literature or employed in commercial practice may be classified in four categories:

(1) Wipers carried on radial supports extending from the rotor axis by fixed rings close to the treating surface. The rings serve to hinge the wipers on an axis parallel to the rotor structure axis, and the wipers have a blade form of relatively small width that can be either straight or bent or curved backwardly. The center of gravity of the wiper blades is located between their hinge axis and the treating surface, and their width is greater than the distance between the hinge axis and the treating surface. As a result, the wiper blades are dragged over the treating surface by the rotor structure so as to squeeze the liquid being treated between their outer edge and the surface, and the wiper blades always make an angle of less than 90° with the treating surface.

(2) Brushes consisting of wires supported from the rotor structure axis and disposed to touch the treating surface.

(3) Bars or little blocks arranged to move over the treating surface and pressed against this surface by centrifugal or spring force.

(4) Blades supported in a fixed relation to the rotor structure axis and radiating in a more or less star-like pattern, with their outer edge disposed near the treating surface and parallel to the rotor structure axis, and with the blades forming any desired angle with the treating surface.

Wipers of the first category and blades of the last category have proved to be the most reliable and to give the best control of the liquid layer.

Brushes of the second category result in good mixing of the liquid, but given an uneven layer thickness. Also, such brushes are difficult to clean and are

objectionably subject to the accumulation of coked material between the wires.

Bars or blocks of the third category have never been successfully employed in commercial practice because they do not make a liquid layer or film properly under varying operating conditions. Either they are pressed too strongly against the treating surface so that the liquid flows down the surace ahead of them in a stream without making a film, or the pressure is not enough to obtain a reliable film control. Also, such bars or blocks are subject to becoming clogged with deposits of the material being treated, and the mechanical friction that results at the treating surface tends to rub particles that are deposited as foreign matter in the material being treated.

The wipers of the first category that are currently known and used results in a relatively high pressure on the liquid film at comparatively low rotating speeds; e.g., rotating speeds corresponding to peripheral speeds of 10 to 14 feet per second. The trailing angular relation of the wipers at the treating surface produces this high pressure on the liquid film through the radial component of the resulting centrifugal force on the wipers during operation, and this pressure provides good mixing and a good control of the film thickness. However, the bubble evaporation in the area under pressure by the wipers is partially or completely eliminated, and this circumstance has been found to be one of the reasons why the heat transfer coefficient between liquid film and treating surface in evaporators equipped with wipers is not affected by the heat flux.

A very different performance is found with thin layer evaporators having fixed blades of the fourth or last category, for when fixed blades are used the heat transfer coefficient varies with the heat flux. Investigations have shown that the reason lies in a basically different action on the liquid layer by the fixed blades.

In using fixed blades, the arrangement must be such that the blades do not touch the treating surface during operation, even though the rotor structure incorporating the blades may be subject to different heat expansion characteristics then the treating surface, but the clearance between blade and treating surface must also be small enough to form a liquid layer of the thickness desired and maintain the working edge of the blade submerged in the liquid layer being formed.

Under these conditions a wave form accumulation of liquid is achieved ahead of the blade when the feed rate is properly maintained. Even if the fixed blade is arranged at an angle other than 90° with respect to the treating surface, no radial pressure is exerted on the liquid layer at peripheral speeds as high as 15 to 50 feet per second or more, although there are pushing and shearing forces that result in excellent mixing of the liquid.

More specifically, the forced flow around the fixed blade edge gives an intensive impulse transfer between the different liquid levels of the layer being made and, therefore, an increased heat transfer results because of the acceleration of liquid particles near the surface. And because there is no radial pressure on the liquid, the bubble evaporation is not affected. The difference in the liquid layer turbulence between wiper blade and fixed blade evaporators is also apparent from the different power requirements for driving the respective rotor structures; the fixed blade evaporator requiring greater driving power to indicate clearly a greater turbulence in its liquid layer.

On the other hand, as the fixed blade evaporator must have a clearance between the blade edge and the treating surface, a minimum feed rate must be maintained to keep the blade edge submerged in the liquid layer being made and obtain the favorable fixed blade action on the liquid layer. If this minimum feed rate is not maintained, the favorable fixed blade action is not only lost, but it is also likely that the treating surface will not remain wetted all over and will accumulate coked deposits of the material being treated.

In the face of the foregoing considerations, the improved means provided according to the present invention makes it possible to obtain the advantages of fixed blade evaporators at smaller feed rates than has heretofore been possible, and at the same time afford some of the advantages of wiper blade evaporators, such as a more automatic control of layer thickness on the treating surface, while achieving maximum heat transfer under the best possible conditions for all feed rates.

Briefly described, the thin layer apparatus of the present invention comprises the usual tubular process chamber fitted with a rotor structure incorporating oscillatory rotor blades for distributing or spreading or making the liquid layer on the inner treating surface of the tubular process chamber. The oscillatory blade elements are hinged to assume a radial position at negligible clearance with respect to the treating surface when no liquid is in the process chamber. This oscillatory arrangement of the blade elements substantially eliminates any radial pressure effect on the liquid, and causes a thin layer spreading of the liquid at minimal clearance and with a high turbulency. Also, because the blade elements are arranged for oscillatory movement, it is not necessary to maintain the extent of clearance from the treating surface that is normally necessary in wiper blade evaporators.

The foregoing and other features and advantages of the present invention are described in further detail below in connection with the accompanying drawings, which show different representative possibilities for employing the invention in thin layer evaporators, and in which:

FIG. 1 is a more or less schematic side elevation of a thin layer evaporator, with the process chamber mainly broken away and sectioned to illustrate an embodiment of the present invention in the rotor structure;

FIG. 2 is a horizontal section taken substantially at the line 2—2 in FIG. 1;

FIG. 3 is an enlarged, fragmentary, side view of a portion of the rotor blading employed in the rotor structure of FIG. 1;

FIG. 4 is a fragmentary section detail taken substantially at the line 4—4 in FIG. 3;

FIG. 5 is a further fragmentary side view comparable to FIG. 3 and illustrating a modified embodiment of the rotor blading;

FIG. 6 is a fragmentary section detail taken substantially at the line 6—6 in FIG. 5;

FIG. 7 is an additional fragmentary side view that is again comparable to FIG. 3 and that illustrates a second modified embodiment of the rotor blading;

FIG. 8 is a fragmentary section detail taken substantially at the line 8—8 in FIG. 7;

FIG. 9 is a fragmentary plan detail corresponding generally to FIG. 2 but showing a modified form of rotor structure incorporating the same sort of blading;

FIG. 10 is a fragmentary side view illustrating a modified hinging arrangement for the rotor blading;

FIG. 11 is a plan detail taken substantially at the line 11—11 in FIG. 10;

FIG. 12 is a side view of an auxiliary element that may be additionally employed in hinging the rotor blading;

FIG. 13 is a fragmentary side view showing the auxiliary element of FIG. 12 assembled for use; and

FIG. 14 is a sectional detail taken substantially at the line 14—14 in FIG. 13.

FIG. 1 shows schematically a counter-current thin layer evaporating apparatus 1 having a separator 2 at the top thereof. The tubular process chamber of the thin layer evaporator 1 consists of two parts 3 and 4 arranged with respective heating jackets 5 and 6, which

may be operated independently. A connecting piece 7 is fixed at the lower end of the evaporator part 4 for directing processed material to an outlet 8 and for supporting a lower bearing (not shown on the figure) for a rotor structure 9. The rotor structure 9 extends lengthwise of the evaporator 1 and through the separator 2 to an axle 10 that is journaled in the cover 11 of the separator 2 and carries a drive pulley 10′ above the cover 11. The rotor structure 9 has a star-like section as shown in FIG. 2, forming an inner space or void 12 throughout the length of the evaporator 1, and the upper part of the rotor 9 in the separator 2 has basically the same shape and operates in relation to baffles 13 within the separator 2. A distribution ring 14 is fixed on the rotor 9 at the level of an inlet feed connection 15 to serve for guidance and distribution of the liquid and to avoid the entrance of liquid droplets in the separation part 2.

Blades 16 are hinged for oscillatory movement at the outer edges of the rotor 9 on an axis parallel to that of the rotor 9. Connection of the blades 16 with the rotor achieved by rings 17. FIGS. 3 and 4 show the blades 16 and the rings 17. Apertures 18 and 19 located at the same level in the blades 16 and the rotor 9 serve for receiving the ring arms 20 and 21 of the ring 17. For use in connecting the blades 16 with the rotor 9, the rings 17 are cut in two parts connected at the section 22 and fixed with an element 23, which can be, for instance, a bolt or a nut or a rivet. Both parts of the ring 17 can be introduced in the apertures 18 and 19 from opposite sides, and can be fixed together by means of the fastener element 23.

The dimensions of the rings 17 and the blades 16 in the radial direction are such that the layer forming blade edges just touch the inner surface 25 of the evaporator parts 3 and 4 when the rotor 9 is rotating at the minimum speed foreseen for operation. To achieve this relation, the blades 16 are initially dragged over the evaporator treating surface 25 to grind or wear the edges of the blades 16 to a proper fit. The result of this initial fitting is that between the blade edges 24 and the surface 25 practically no clearance will remain, if the blades 16 have been installed to touch the treating surface at the begining of the fitting operation. The ultimate clearance can be increased by first using rings 17 of a larger diameter during the fitting operation and afterwards replacing them with normal rings.

With the rotor 9 rotating at normal speed, the oscillatory blades have an absolutely radial position and the edges 24 thereof have practically no clearance at the surface 25. When a liquid layer is being formed on the surface 25, the blades 16 hang backwards, pushing a certain amount of liquid ahead of them (schematically shown at 26 in FIG. 4). Under normal operation, when the rotor 9 is rotating at a certain speed and the feed rate is constant, the blades 16 take a certain operating position. The clearance between treating surface 25 and blade edge 24 is then always smaller than the thickness of the liquid layer 26 on the wall 25. The blades 16 thus, at a given feed rate, submerge a certain distance in the liquid layer 26 to cause a high turbulency, and hence an increase heat transfer coefficient, even with comparatively thin liquid layers. At the same time, the heat transfer coefficient is not affected by any radial pressure through centrifugal force upon the liquid layer, and bubble formation in the liquid layer remains unimpaired. In addition, the relation of the oscillatory blades 16 make it practically impossible for the surface 25 to be unwetted at any portion.

It should also be noted, as seen in FIGS. 3 and 4, that the clearance 27 between rotor structure 9 and blade 16 allows a movement of the oscillatory blade 16 in an axial direction as well. This happens, for instance, when the rotor 9 is at rest so that no centrifugal force on the blades 16 reacts against their gravity. Such axial movement substantially increases the clearance between the blade edge

24 and the treating surface 25 and greatly facilitates removal of the rotor structure 9 whenever necessary.

FIGS. 5 and 6 show an example of a modified oscillatory blade 30 embodying the present invention, which is hinged to a fixed blade 33 of a rotor 34 by means of two rings 31 and 32 having different diameters. FIG. 6 shows the position of the blade 30 when it is hanging backwards due to the resistance in the liquid layer. Because ring 32 has a bigger diameter than ring 31, the blade 30 has an inclined hinging axis, compared to the axis of the rotor 34, which is given by the two centers $m31$ and $m32$. This inclination of the blade axis makes the clearance between blade edge 24 and treating surface 25 vary lengthwise of the blade when it moves from its radial position. In the example of FIGS. 5 and 6 this clearance is bigger at the lower end of the blade 30 than at its upper end. It is possible, by the same means, to incline the layer forming edge of the blade 30 from its vertical position, and thereby affect the down flow of liquid along the treating surface 25 as the layer forming clearance can either speed up or slow down this flow depending on how the inclination is chosen.

A similar effect can also be achieved by arranging the blade 30 as shown in FIGS. 7 and 8. Here the hinging axis is again inclined compared to the axis of the rotor 34 by means of two rings 31 of the same size that are carried on a fixed blade. 33' at different distances from the axis of the rotor 34. As the lower ring 31 is located at a greater distance from the axis of the rotor 34 than the upper ring 31, the arrangement of FIGS. 7 and 8 allows a free movement of the blade 30 in a direction parallel to the axis of the rotor 34, whereas this free movement is not possible with the arrangement of FIGS. 5 and 6. In both modifications shown by FIGS. 5 to 8, the blade 30 has an original position at 90° with respect to the treating surface 25, and its outer edge 24 may have minimal clearance at the surface 25.

FIG. 9 shows an example of hollow fixed blades or vanes 35 arranged on a hollow rotor 36 so as to provide an enclosed space that may serve, for instance, for jacketing the flow of a cooling medium. Additional fixed blade elements 37 are provided to carry oscillatory blades 38 by means of rings 39. The arrangement and design of the oscillatory blades 38 is comparable to those shown in FIGS. 1 and 2. The effect or action of all the oscillatory blade forms described above is basically the same, with the difference that by providing for inclination of the layer forming blade edge the flow characteristics of the liquid layer can be influenced.

Also, it is possible to use one-piece hinging rings, instead of rings consisting of several parts as shown in FIG. 4, to connect the fixed and movable parts of the rotor structure. Possibilities are shown in FIGS. 10 to 14. As shown in FIGS. 10 and 11, the blade 40 and the rotor 41 have apertures 42 and 43 which are threaded. Each aperture 42 and 43 has a lateral opening 44 and 45 to the outside. These openings 44 and 45 are such that a hinging ring 46 can be introduced therethrough to the apertures 42 and 43. Discs 47 and 48 have central openings 49 and 50 for the ring 46, as well as lateral openings 51 and 52 to introduce the ring 46 in the openings 49 and 50. The discs 47 and 48 can then be screwed in the threaded apertures 42 and 43, with their lateral openings 51 and 52 displaced with respect to the lateral openings 44 and 45, and preferably arrange oppositely. Once these discs 47 and 48 have been positioned properly they may be fixed in place by means of wedges 53 and 54 inserted at the lateral openings 51 and 52.

In FIGS. 12 to 14, there is illustrated a further possibility of employing discs 55 that provide an eccentric ring mounting aperture 56 for adjusting the blade edge clearance. The discs 55 are made of two parts 55A and 55B as shown in FIG. 12, and FIGS. 13 and 14 show how these discs 55 can be assembled and fixed in place. For this purpose, the rotor blade 57 formed with a lateral opening 58 through which a hinging ring 59 can be introduced into a blade aperture 60. Both parts of the disc 55A and 55B have cogged shoulders 61 that serve to hold them at a selected position when fixed in place by a retaining ring 62. Use of such discs 55 allows an easy adjustment of the blades 57 and further allows an easy replacement of discs 55 and rings 59 if this becomes necessary after a certain period of operation.

The advantage in using rings to hinge the oscillatory blades is that the operating motion of the blades cannot be readily affected by deposits of the material being processed. Furthermore, hinging with rings is very simple so that assembly and disassembly as well as replacement of parts can be made in a short time and at low cost. Additionally, ring hinging offers the possibility of influencing the thickness of the liquid layer during operation.

It should also be noted that the clearance between oscillatory blades and treating surface may be varied by varying the rotating speed of the rotor, as such variation influences the centrifugal force on the blades so that there is a certain clearance obtained in correspondence with a certain rotating speed. Also, the position of the blades during operation can be additionally influenced by springs so as to maintain a certain clearance and operating action of the blades over a range of rotating speeds, independently of the weight of the blades.

In all the illustrated examples, the rotor structure is shown with fixed blade or vane members presenting continuous surfaces between the oscillatory blades and lengthwise of the apparatus, as such an arrangement enhances the separation effect obtained during operation. It is also possible, however, to hinge the oscillatory blades on any other suitable supporting structure arranged for rotation about the central axis of the apparatus.

The present invention has been described in detail above for purposes of illustration only and is not intended to be limited by this description or otherwise except as defined in the appended claims.

I claim:

1. An oscillatory rotor blade for fluent material processing apparatus of the type in which fluent material is spread in thin layer form over the inner surface of a tubular process chamber by a rotor structure mounted axially within said chamber, said blade forming an active layer spreading element of said rotor structure and said blade being characterized, in combination with said process chamber and rotor structure, by a hinged mounting on said rotor structure about a coplanar axis displaced radially from the axis of said rotor structure and by a radial extent when fully extended from said hinging axis proportioned to reach radially short of actual contact with the inner surface of said process chamber for presenting a layer spreading edge thereof at minimal clearance with respect to said surface on which said fluent material is to be spread.

2. An oscillatory rotor blade as defined in claim 1 and further characterized in that the coplanar axis about which said blade is hinged has an inclination with respect to the axis of said rotor structure.

3. An oscillatory rotor blade as defined in claim 1 and further characterized in that the hinged mounting of said blade in said rotor structure comprises ring members received and retained freely within respective apertures provided in said rotor structure and said blade so that the latter is rendered both axially and oscillatably movable with respect to the former.

4. A rotor structure for fluent material processing apparatus in which the rotor structure rotates about a central axis within a tubular process chamber to spread fluent material in a thin layer over the inner chamber surface for processing treatment, said rotor structure comprising, in combination with said process chamber, an inner rigidly constructed supporting portion, and at least one blade member hinged on said supporting portion for oscillatory movement about a coplanar axis displaced radially from the axis of said structure, said blade member being proportioned in radial extent to reach radially when fully extended from said hinging axis to a disposition short of actual contact with the inner surface of said process chamber for presenting a layer spreading edge thereof at minimal clearance with respect to said surface on which said fluent material is to be spread.

5. A rotor structure as defined in claim 4 and further characterized in that the coplanar axis about which said blade member is hinged on said rotor structure supporting portion is parallel to the axis of said rotor structure.

6. A rotor structure as defined in claim 4 and further characterized in that the coplanar axis about which said blade member is hinged on said rotor structure supporting portion is inclined with respect to the axis of said rotor structure.

7. A rotor structure for fluent material processing apparatus in which the rotor structure rotates within a tubular housing to spread fluent material in a thin layer over the inner surface of the housing for processing treatment, said rotor structure comprising, in combination with said tubular housing, an inner rigidly constructed supporting portion carried for rotation about the axis of said tubular housing, and a plurality of blade members hinged outwardly at spaced lengthwise positions on said supporting portion for oscillatory movement about a coplanar axis displaced radially from said housing axis, each of said blade members being proportioned in radial extent to reach radially when fully extended from said hinging axis to a disposition short of actual contact with the inner surface of said tubular housing for presenting respective layer spreading edges thereof at minimal clearance with respect to the inner surface of said tubular housing.

8. In apparatus for treatment of fluent material in thin layers and incorporating for this purpose a tubular housing having a rotor structure rotating about the lengthwise axis thereof for spreading fluent material in a thin layer over the inner surface of the housing, the improvement which comprises at least one layer spreading blade member hinged on said rotor structure for oscillatory movement about a coplanar axis displaced outwardly from the axis of said rotor structure, said blade member being proportioned in radial extent to reach radially when fully extended from said hinging axis to a disposition short of actual contact with said inner surface of the housing for presenting a layer spreading edge of said blade member at minimal clearance with respect to the inner surface of said tubular housing.

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