

Description

The present invention relates to dispersion and grinding and more particularly to dispersion of solid particles suspended in liquid using cylinders, balls or the like.

Utilization of balls for grinding is a known art. Among the known devices are ball mills, which comprise a container filled with grinding particles such as steel or ceramic balls and apparatus for stirring or agitating the balls. When particulate matter is introduced into the container, the agitation has the effect of reducing the size of the particles. The effectiveness of these devices are, in the main, limited to situations in which the particles to be ground are much smaller than the grinding particles and are suspended in a liquid.

A number of publications disclose the use in grinding of balls or other particles contained between two surfaces. In United States Patent 276,418 there is disclosed a shoe and die for amalgamating pans in which "pulp and tailing from the battery...is ground together with quicksilver". In one of the embodiments described, grinding rollers are made to roll over a flat die.

United States Patent 3,044,716 describes pulverizing mills in which balls are made to run in a circular raceway between two plates, the plates being entirely flat other than at the raceway. Material to be ground is fed into the center of a mill, passes through the raceway, and is ground before exiting on the periphery of the device.

United States Patents 4,225,092 and 4,496,106 describe wet mills in which the grinding region is an annular volume defined between a stationary outer cylinder and a rotating inner cylinder. In both cases the annulus is filled with the material to be ground and the liquid carrier, to which are added generally spherical grinding elements having dimension much smaller than the thickness of the annulus.

United States Patents 3,511,447 and 4,730,789 describe mills with attritive elements within variously configured grinding regions. The grinding regions are defined by moving and stationary surfaces and the attritive elements are much smaller than the smallest dimension of the grinding region. In both these patents there are intermediate (non-grinding) regions separating different grinding regions. During operation, the attritive elements are not present in the intermediate regions. In 3,511,447 the intermediate regions have a smallest dimension smaller than the smallest dimension of the elements; in 4,730,789 the regions have a smallest dimension slightly greater than the minimum dimension of the elements, with the elements being swept from these regions either by centrifugal or magnetic forces.

USSR Patent publication SU 445,466, discloses a mill for grinding ore, comprising an inner stationary truncated cone which is separated from an outer rotatable truncated cone by a plurality of crushing balls. Springs resiliently press the inner cone into engagement with the balls. Flexible material is provided on the surface of the inner cone facing the balls. In operation, material to be ground is fed through windows in a plate covering the mill and is thrown, due to centrifugal force, to the periphery of the outer cone, where it falls into a space between the two cones. The balls grind the material and the ground material then falls to the bottom and exits.

For dispersion of solids in liquids, where the mixture is highly viscous, as the solids and fluids used in the preparation of lithographic inks, three- or five-roll mills are used in which relatively large rollers, each rotating at a different speed, are almost in contact with one another, with a slight clearance between. Material fed into these mills is subjected to strong shear forces when passing between the rollers, the shear forces being operative both to reduce particle size and to improve dispersion of the solid material in the fluid.

These mills are relatively large and expensive and require considerable attention during operation. In particular, feeding, cleaning and material removal must be attended to. A further disadvantage of these mills is that the degree of dispersion achieved is often unsatisfactory, and consequently, the material must often be processed repeatedly until a desired fineness is achieved. Also, the mills are open to the atmosphere, resulting in substantial discharge of hydrocarbon vapors. Therefore, and in order to reduce health hazards and to avoid changes in ink characteristics, ink temperatures must be kept low.

U. S. Patent 3,679,141 describes a shear mill having long cylindrical rods in an annular region between two concentric cylindrical surfaces, the inner one of which rotates. At least one of the rods is linked to the rotating surface such that all of the rods move with the velocity of that surface.

The present invention seeks to provide improved apparatus and techniques for dispersion of solids suspended in liquids.

There is therefore provided, in accordance with a preferred embodiment of the invention apparatus for dispersion of solids in liquids comprising:

a) first and second relatively movable elements having respective first and second surfaces having a separation distance therebetween and arranged so as to define a dispersing volume therebetween;

b) a multiplicity of dispersing elements disposed within the dispersing volume;

c) means for supplying a solid suspended in liquid to the dispersing volume and for removing a dispersed form of the solid suspended in liquid; and

d) means for effecting relative movement between the first and second surfaces;

characterized in that:

the multiplicity of elements forms a single layer in said dispersing volume;

movement is imparted to the dispersing elements mainly by means of hydrodynamic forces created by the relative movement;

the dispersing elements move at a velocity different from the velocity of both the first and second surfaces; and

the solids are subjected to high shear forces operative to break up and disperse the solids in the liquid.

In a preferred embodiment of the invention the multiplicity of dispersing elements form a single layer and are mechanically mutually uncoupled except by hydrodynamic forces.

Preferably, the dispersing elements have a circular cross-section having a diameter which is between 2 and 100 micrometers less than the separation distance.

In one preferred embodiment of the invention, the dispersing elements comprise generally spherical elements. Preferably, the separation distance is greater than about 5 micrometers more, preferably between about 20 and 70 micrometers more than the diameter.

In a second preferred embodiment of the invention the dispersing elements comprise generally cylindrical elements. Preferably, the separation distance is greater than about 5 micrometers more, preferably between 10 and 25 micrometers more, than the diameter.

In a preferred embodiment of the invention the dispersing elements are kept substantially non-contacting with the first and second movable surfaces mainly as a result of hydrodynamic forces.

Preferably, the means for effecting relative movement is operative to cause the dispersing elements to rotate mainly as a result of hydrodynamic forces.

In a preferred embodiment of the invention the first and second surfaces are concentrically disposed defining an annular dispersing volume and the dispersing elements are circumferentially closely spaced, preferably by a spacing less than 25 micrometers, more preferably, about 10 micrometers.

Preferably, the apparatus includes means for forcing the solid suspended in the liquid between the said dispersing elements whereby the solid is subjected to high shear forces and is dispersed in the liquid.

In a preferred embodiment of the invention the dispersing volume is delimited by retaining elements associated with at least one of the first and second elements. Preferably, the means for supplying and removing includes means for supplying the solid suspended in the liquid to the dispersing volume at a location intermediate the retaining elements.

In a preferred embodiment of the invention, the dispersion of solids in liquid is a lithographic ink.

There is further provided in accordance with a preferred embodiment of the invention a method for dispersion of solids in liquids comprising the steps of:

introducing a solid suspended in a liquid into a dispersing volume defined by first and second respective surfaces of first and second relatively movable elements, the volume having disposed therein a multiplicity of dispersing elements; and

effecting relative movement between said first and second surfaces,

characterized in that the step of effecting relative movement is operative to impart movement to the dispersing elements mainly by means of hydrodynamic forces created by the relative movement and to subject the solids to high shear forces operative to break up and disperse the solids in the liquid; and

wherein the dispersing elements form a single layer in the dispersing volume.

Preferably, the dispersing elements are mutually mechanically unlinked except by hydrodynamic forces.

In a preferred embodiment of the invention, the dispersing elements have a circular cross-section having a diameter which is between 2 and 100 micrometers less than the separation distance.

Preferably, the dispersing elements are kept substantially non-contacting with the first and second movable surfaces, preferably, mainly as a result of hydrodynamic forces.

In a preferred embodiment of the invention the step of effecting relative movement is operative to cause the dispersing elements to rotate mainly as a result of hydrodynamic forces.

Preferably, the first and second surfaces are concentrically disposed defining an annular dispersing volume and the dispersing elements are circumferentially closely spaced, preferably, by less than about 25 micrometers, more preferably, by about 10 micrometers.

In a preferred embodiment of the invention the method further includes the step of forcing the solid suspended in the liquid between the dispersing elements whereby the solid is subjected to high shear forces and is dispersed in the liquid.

Preferably, the dispersion of solids in liquid is a lithographic ink.

The present invention will be understood and appreciated more fully from the following detailed description, taken in conjunction with the drawings in which:

Fig. 1 is a sectional illustration of dispersing apparatus constructed and operative in accordance with a preferred embodiment of the present invention;

Fig. 2 is a sectional illustration of a portion of dispersing apparatus constructed and operative in accordance with an alternative embodiment of the present invention;

Fig. 3 is a sectional illustration of another alternative embodiment of dispersing apparatus constructed and operative in accordance with another alternative embodiment of the present invention;

Fig. 4 is an enlarged sectional illustration of a portion of the apparatus of Fig. 3;

Fig. 5 is a sectional illustration of another portion of the apparatus of Fig. 3;

Fig. 6 is an enlarged sectional illustration of a portion of an alternative dispersing apparatus constructed and operative in accordance with another alternative embodiment of the present invention;

Fig. 7 is a sectional illustration of dispersing apparatus constructed and operative in accordance with yet another preferred embodiment of the present invention; and

Fig. 8 is an enlarged sectional illustration of a portion of the apparatus of Fig. 7.

Reference is now made to Fig. 1, which illustrates, in section, apparatus for dispersion of solids suspended in liquids including first and second relatively moving elements arranged so as to define a dispersing volume therebetween, a multiplicity of dispersing elements disposed within the dispersing volume and apparatus for supplying a solid suspended in a liquid to the dispersing volume for dispersing and for removing a dispersed solid suspended in a liquid from the dispersing volume after dispersing, wherein the first and second relatively moving elements are separated at the dispersing volume by a separation distance which is greater than the maximum dimension of the dispersing elements.

In the illustrated embodiment, one of the first and second relatively moving elements comprises a stationary element 10 which defines a generally cylindrical bore 12 in which is rotatably mounted a rotating generally cylindrical element 14. Element 14 is rotatably mounted with respect to element 10 in bore 12 by means of bearings 16, typically as shown. An annular dispersing volume 18 is defined at bore 12 between an outer surface 20 of element 14 and a corresponding inner surface 22 of element 10.

An inlet 24 for supply of a solid suspended in a liquid, such as lithographic ink, typically extends vertically in communication with volume 18, preferably at a central location thereof, as illustrated. Outlets 26 for removal of dispersed materials are provided in communication with volume 18 at side locations thereof.

According to a preferred embodiment of the invention, surfaces 20 and 22 of the dispersing volume 18 are preferably formed of an abrasion resistant material.

In accordance with a preferred embodiment of the invention there is disposed in the dispersing volume 18 a single layer of dispersing elements 30, preferably spherical balls formed of a hard material, such as tungsten carbide and of diameter 0.8 mm. According to a preferred embodiment of the invention, the annular separation between surfaces 20 and 22 at the dispersing volume 18 is approximately between 0.005 to 0.10 mm larger than the diameter of the balls 30, preferably 0.02 to 0.07 mm.

Dispersing elements 30 are retained in volume 18 by inner and outer retaining rings 32. Additional retaining rings 32 may be provided intermediate the inner and outer rings for separating groups of elements 30 and thus subdividing the dispersing volume 18, thereby to provide enhanced resistance to the pressure of elements 30 being forced into engagement therewith. This is believed to provide improved mixing of the dispersion.

According to a preferred embodiment of the invention, cooling fluid circulation is provided through both elements 10 and 14. In element 10 an annular cooling fluid passageway 36 is defined extending in spaced, generally parallel relationship to surface 22 in communication with a cooling fluid inlet 38 and cooling fluid outlets 40. In rotating element 14, an annular cooling fluid passageway 42 is defined in spaced, generally parallel relationship to surface 20 in communication with a cooling fluid inlet 44 and cooling fluid outlet 46. It is appreciated that in this embodiment, a rotatable fluid coupling is provided in association with inlet 44 and outlet 46.

The operation of the apparatus of Fig. 1 will now be summarized. Solid particles suspended in a liquid carrier, such as for example, lithographic inks or liquid toner concentrate, is introduced under pressure, typically of 5 to 15 Bar or greater pressure, via inlet 24 to dispersing volume 18. Rotating element 14 is typically rotated relative to element 10 about an axis 50 at a relatively high speed, typically 2000 - 3000 RPM, by a motor (not shown).

It is believed that mainly as a result of hydrodynamic forces, the dispersing elements 30 are rotated and kept substantially non-contacting

with surfaces 20 and 22 and move circumferentially at a velocity intermediate the velocities of surfaces 20 and 22. As the solid particles in the liquid carrier are forced into the space the dispersing elements 30 and surfaces 20 and 22, and in the space surrounding the elements 30, under pressure, they are subjected to high shear forces breaking up and dispersing the solid particles in the liquid carrier. The dispersed material exits via outlets 26.

Cooling fluid, typically water, is pumped through the cooling fluid passages described above, thus cooling the elements 10 and 14, and the material in the dispersing volume 18.

Reference is now made to Fig. 2, which illustrates an alternative embodiment of dispersion apparatus, wherein like features are illustrated by identical reference numerals. Here, in contrast with the operation of the apparatus of Fig. 1, the material to be dispersed is supplied under pressure to one side of the volume and removed from the opposite side, producing pressure loading on the dispersing elements 30. In the embodiment of Fig. 1, in contrast, the supply of the material to be dispersed is at an intermediate location along the volume 18.

In a practical example of the operation of the apparatus of Fig. 2, the length of the dispersing volume 18 is approximately 70 mm, the diameter of the dispersing volume 18 is approximately 70 mm, the dispersing elements 30 have a diameter of 0.80 mm and are formed of tungsten carbide, and the spacing between surfaces 20 and 22 is 0.83 mm. The apparatus is operated with an input of non-milled black lithographic ink base with a Hegman Drag reading of less than 6 at an input pressure of 13 Bar, an input material temperature of 45 degrees C and an output temperature of 80 degrees C and a throughput of 250 grams/minute. The rotation rate of element 14 is 2550 RPM and the power required for rotation is 10 KW. The output material has a Hegman Drag reading of between 7.8 and 8. Water is employed as a cooling fluid and circulated at a rate of about 30 liters/minute, producing a temperature rise of the water of 1.3 degrees C.

In order to clarify details, Figures 1 and 2 are not drawn to scale. From the example it should be noted that the annular spacing between surfaces 20 and 22 is relatively much smaller than shown. Furthermore, the number of dispersing elements is about 30,000 and not as shown.

A third embodiment of the invention is shown in Figs. 3 - 5. Here, the dispersing elements comprise rollers which travel in a raceway formed in an annular region between a stationary outer surface and a moving inner surface.

As shown in Figs. 3 and 4, a disperser 60 is formed of a generally cylindrical inner shaft 62 and a stationary outer cylinder 64. A plurality of roller dispersers 66 each comprising an outer conical ring 68, an inner conical ring 70 and a plurality of cylindrical rollers 72, are located in a volume defined between inner shaft 62 and outer cylinder 64. Adjacent roller dispersers 66 are spaced from each other by outer and inner annular clutch rings 74 and 76.

Inner ring 70 is formed with radial end stops 71 to form a raceway for the rollers 72, and in a preferred embodiment of the invention a retaining cage or ring (not shown) retains the rollers 72 in operative association with inner ring 70.

As illustrated in Fig. 4, alternating roller dispersers 66 are reversed in axial orientation, such that outer clutch rings 74 are abutted by outer conical rings 68 of two adjoining dispersers 66 and inner clutch rings 76 are abutted by the inner conical rings 70 of two adjoining roller dispersers 66.

Outer cylinder 64 has formed therein a longitudinal key-way 78. A key formed on the outer periphery of each of rings 74 engages key-way 78 for retaining rings 74 stationary with respect to cylinder 64. Similarly inner shaft 62 has formed therein a key-way 80 which, in conjunction with cooperating keys in inner rings 76, causes the rings to rotate together with the shaft 62.

In Fig. 5 there is illustrated an embodiment of apparatus for providing a resilient axial force to press roller dispersers 66 against adjoining clutches 74 and 76, thereby to force respective rollers 72 into pressure engagement with inner and outer rings 68 and 70 while the shaft 62 is not rotating.

A cylindrical pusher 90 is arranged to press against the inner ring 70 of the outermost roller grinder 67. Cylindrical pusher 90 comprises a cylindrical portion 91 which slides over shaft 62. One end 93 of pusher 90 contacts the outermost roller grinder 66 at the inner ring thereof and the other end defines a spring seat 92.

A threaded ring 94 is screwed onto an end threaded portion 95 of an extension of shaft 62, and in cooperation with spring seat 92 compresses a compression spring 96, thereby resiliently urging end 93 of cylindrical portion 91 against inner ring 70 of the extreme roller grinder 66.

By changing the position of ring 94 on threaded portion 95, the pressure on the roller dispersers 66 and clutches 74 and 76 can be adjusted. An end stop 96, shown in Fig. 4, provides a counter force at the other end of the stack.

Disperser 60 is provided with an inlet 100 and an outlet 102 for feeding viscous material containing particles and agglomerates to be dispersed and

for removing dispersed material. An example of such material to be dispersed is non-milled lithographic ink, and the output desired is lithographic ink with finely dispersed particles.

One or more cooling manifolds 120, with cooling fluid inlets and outlets 122 and 124 are provided to allow for cooling of outer cylinder 64. Additionally or alternatively shaft cooling can be provided as illustrated in Figs. 1 and 2.

In operation shaft 62 is caused to rotate by a belt 110 driven by a motor 112 or by any other convenient means. Pressure of inner rings 70 against inner clutches 76, causes the inner rings 70 to rotate with the shaft 62, while similar pressure causes the outer rings 68 to remain stationary. Owing to the dimensions of the moving members, cylindrical rollers 72 are made to rotate at a rotation rate many times that of shaft 62.

Upon rotation of rollers 72, because of the high viscosity of the material being dispersed, hydroplaning action results providing a force perpendicular to the interface between rollers 72 and rings 68 and 70. One component of this force acts to increase the axial extent of each of roller dispersers 66 and thus to form a gap between each of rollers 72 and adjacent rings 68 and 70. The viscous material to be dispersed passes between the inner and outer rings 68 and 70, and is disposed in the vicinity of rollers 72, and in the space between the inner and outer rings 68 and 70 and rollers 72.

In an alternative arrangement, the spring 92 is replaced by resilient solid material.

In a preferred embodiment of the invention, the spring is omitted and the threaded ring 94 is axially positioned a small distance from seat 92. Upon rotation of shaft 62, hydrodynamic forces, as described above push pusher 90 against ring 94. In this case the total roller-ring spacing is fixed by the axial position of ring 94. The division of the total roller spacing among the dispersers 66 will depend of the changes in viscosity of the material being dispersed as it travels from the inlet to the outlet.

High shear is produced in the spaces between and adjacent rollers 72 and rings 68 and 70 and causes agglomerates in the dispersion to break up and the resulting particles to be finely dispersed.

In a practical example of the embodiment of Figs. 3 - 5 the diameter of shaft 62 is typically 45 mm and the inner diameter of cylinder 78 is typically 75 mm. Forty roller dispersers 66 which preferably comprise twenty spaced rollers 72 of circular cross sectional diameter of approximately 6 mm. The axis of rollers 72 form an angle of approximately 15 degrees with the axis of shaft 62.

The dispersers 66 are spaced by clutches 74 and 76 made of 2 mm stainless steel sheet. The clutches 74 and 76 may have roughened bearing surfaces, but this has not been found to be neces-

sary, due to the high pressure forces involved.

Alternatively, as shown in Fig. 6 the clutches may be omitted. For this embodiment of the invention an outer keyway 82 is formed in each outer ring 68 and an inner keyway 84 is formed in each inner ring 70. An inner key 86 and an outer key 88 placed in keyways 82 and 84 respectively provide for the associated outer rings 68 to remain stationary with outer cylinder 64, and for the associated inner rings 70 to rotate with shaft 62.

In a typical application, shaft 62 is rotated at about 3000 RPM, and rollers 72 rotate at a rate of about 30,000 RPM. The ink is fed into the disperser at a pressure of approximately one atmosphere. Under these conditions the power requirement is approximately 8 KW and the throughput is approximately 400 g/min., with a roller-ring spacing of approximately 5-10 microns.

Reference is now made to Figs. 7 and 8 which show, schematically, a fourth embodiment of the invention similar in general structure to the embodiment shown in Fig. 1, except that the spherical dispersing elements 30 are replaced by a multiplicity of cylindrical dispersing elements 104.

For this embodiment the diameter of dispersing elements 104 is preferably 800-3500 microns and their length is 6-20 mm, more preferably 1000-2500 microns and 9-12 mm respectively. The radial dimension of dispersing volume is preferably 5-25 microns, more preferably 10-15 microns greater than the diameter of dispersing elements 104. For this construction, the cylindrical dispersing elements can be circumferentially relatively closely packed with preferably only about 10 microns clearance between the cylindrical dispersing elements.

In an exemplary example of the embodiment of Figs. 7 and 8, surface 20 is cylindrical with a diameter of 31.77 mm and surface 22 is cylindrical with a diameter of 36.79 mm. Dispersing element 104 has a diameter of 9.8 mm and is 9.8 mm long. 55 dispersing sections are utilized. It was found that for this configuration very high quality dispersion was achieved for high throughput, at much lower power than for the other embodiments.

It will be appreciated by persons skilled in the art that the specific dimensions, numbers of dispersers 66, cylindrical dispersing elements 104 and rollers 72 and rotation speed may be varied over a wide range in the practice of the invention, consistent with providing the required shear force on the dispersion.

It should be noted that proper roller-ring spacing (which may derive from proper resilient axial force or from the position of ring 90) is important to optimal operation of this embodiment of the invention. The proper force or spacing is determined empirically for each combination of parameters of

the disperser structure and operation, material to be dispersed and quality of dispersion required. Too small a spacing (or too great a force causing reduced or no roller-ring clearance) results in increased power requirements and wear, well as excessive heating. Too large a spacing (or too low a force resulting in increased roller-ring spacing) results in decreased shear, producing poor dispersion.

For proper operation the spacing between the rings 68 and 70 for the embodiment of the invention shown in Figs. 3- 6 should be 0.004 to 0.10 mm greater than the diameter of roller 72, resulting in a roller-ring spacing of .002 to .050 mm.

The method and apparatus of the invention works well with lower viscosity materials as well. In a particular example the embodiment of Fig. 2 with dimensions as in the practical example give in the explanation of that embodiment given above, and with a rotation rate of 3000 RPM is used to disperse magnetic recording material in a carrier liquid Toluene and MEK prior to coating of the substrate of the magnetic recording media. The results of such dispersion gives a uniformly dispersed contaminant free dispersion. Other embodiments of the invention can also be used for the dispersion of magnetic recording material.

The method and apparatus of the invention is also suitable for the dispersion of paint and other similar material.

It will be appreciated by persons skilled in the art that the present invention is not limited by what has been particularly shown and described hereinabove. Rather the scope of the present invention is defined only by the claims which follow.

Claims

1. Apparatus for dispersion of solids in liquids comprising:

- a) first and second relatively movable elements (10, 14 or 68, 70) having respective first and second surfaces (22, 20) having a separation distance therebetween and arranged so as to define a dispersing volume (18) therebetween;
- b) a multiplicity of dispersing elements (30, 72 or 104) disposed within the dispersing volume;
- c) means (24, 100, 102) for supplying a solid suspended in liquid to the dispersing volume and for removing a dispersed form of said solid suspended in liquid; and
- d) means (110, 112) for effecting relative movement between said first and second surfaces;

characterized in that:

the multiplicity of elements forms a sin-

gle layer in said dispersing volume;

movement is imparted to the dispersing elements mainly by means of hydrodynamic forces created by the relative movement;

the dispersing elements move at a velocity different from the velocity of both the first and second surfaces; and

the solids are subjected to high shear forces operative to break up and disperse the solids in the liquid.

2. Apparatus according to claim 1 wherein the multiplicity of dispersing elements are mechanically mutually uncoupled except by hydrodynamic forces.
3. Apparatus according to claim 1 or claim 2 wherein said dispersing elements have a circular cross-section having a diameter which is between 2 and 100 micrometers less than said separation distance.
4. Apparatus according to any of the preceding claims wherein said dispersing elements comprise generally spherical elements.
5. Apparatus according to claim 4 wherein said separation distance is greater than about 5 micrometers more than said diameter.
6. Apparatus according to claim 5 wherein said separation distance is between about 20 and 70 micrometers more than said diameter.
7. Apparatus according to any of claims 1-3 wherein said dispersing elements comprise generally cylindrical elements.
8. Apparatus according to claim 7 wherein said separation distance is greater than about 5 micrometers more than said diameter.
9. Apparatus according to claim 8 wherein said separation distance is between about 10 and 25 micrometers more than said diameter.
10. Apparatus according to any of the preceding claims and further characterized in that said dispersing elements are kept substantially non-contacting with said first and second movable surfaces.
11. Apparatus according to any of claims 1-10 and further characterized in that said dispersing elements are kept substantially non-contacting with said first and second movable surfaces mainly as a result of hydrodynamic forces.

the disperser structure and operation, material to be dispersed and quality of dispersion required. Too small a spacing (or too great a force causing reduced or no roller-ring clearance) results in increased power requirements and wear, well as excessive heating. Too large a spacing (or too low a force resulting in increased roller-ring spacing) results in decreased shear, producing poor dispersion.

For proper operation the spacing between the rings 68 and 70 for the embodiment of the invention shown in Figs. 3- 6 should be 0.004 to 0.10 mm greater than the diameter of roller 72, resulting in a roller-ring spacing of .002 to .050 mm.

The method and apparatus of the invention works well with lower viscosity materials as well. In a particular example the embodiment of Fig. 2 with dimensions as in the practical example give in the explanation of that embodiment given above, and with a rotation rate of 3000 RPM is used to disperse magnetic recording material in a carrier liquid Toluene and MEK prior to coating of the substrate of the magnetic recording media. The results of such dispersion gives a uniformly dispersed contaminant free dispersion. Other embodiments of the invention can also be used for the dispersion of magnetic recording material.

The method and apparatus of the invention is also suitable for the dispersion of paint and other similar material.

It will be appreciated by persons skilled in the art that the present invention is not limited by what has been particularly shown and described hereinabove. Rather the scope of the present invention is defined only by the claims which follow.

Claims

1. Apparatus for dispersion of solids in liquids comprising:

- a) first and second relatively movable elements (10, 14 or 68, 70) having respective first and second surfaces (22, 20) having a separation distance therebetween and arranged so as to define a dispersing volume (18) therebetween;
- b) a multiplicity of dispersing elements (30, 72 or 104) disposed within the dispersing volume;
- c) means (24, 100, 102) for supplying a solid suspended in liquid to the dispersing volume and for removing a dispersed form of said solid suspended in liquid; and
- d) means (110, 112) for effecting relative movement between said first and second surfaces;

characterized in that:

the multiplicity of elements forms a sin-

gle layer in said dispersing volume;

movement is imparted to the dispersing elements mainly by means of hydrodynamic forces created by the relative movement;

the dispersing elements move at a velocity different from the velocity of both the first and second surfaces; and

the solids are subjected to high shear forces operative to break up and disperse the solids in the liquid.

2. Apparatus according to claim 1 wherein the multiplicity of dispersing elements are mechanically mutually uncoupled except by hydrodynamic forces.
3. Apparatus according to claim 1 or claim 2 wherein said dispersing elements have a circular cross-section having a diameter which is between 2 and 100 micrometers less than said separation distance.
4. Apparatus according to any of the preceding claims wherein said dispersing elements comprise generally spherical elements.
5. Apparatus according to claim 4 wherein said separation distance is greater than about 5 micrometers more than said diameter.
6. Apparatus according to claim 5 wherein said separation distance is between about 20 and 70 micrometers more than said diameter.
7. Apparatus according to any of claims 1-3 wherein said dispersing elements comprise generally cylindrical elements.
8. Apparatus according to claim 7 wherein said separation distance is greater than about 5 micrometers more than said diameter.
9. Apparatus according to claim 8 wherein said separation distance is between about 10 and 25 micrometers more than said diameter.
10. Apparatus according to any of the preceding claims and further characterized in that said dispersing elements are kept substantially non-contacting with said first and second movable surfaces.
11. Apparatus according to any of claims 1-10 and further characterized in that said dispersing elements are kept substantially non-contacting with said first and second movable surfaces mainly as a result of hydrodynamic forces.



12. Apparatus according to any of the preceding claims wherein said means for effecting relative movement is operative to cause said dispersing elements to rotate mainly as a result of hydrodynamic forces.
13. Apparatus according to any of the preceding claims wherein said first and second surfaces are concentrically disposed defining an annular dispersing volume and said dispersing elements are circumferentially closely spaced.
14. Apparatus according to claim 13 wherein said dispersing elements are circumferentially spaced by less than about 25 micrometers.
15. Apparatus according to claim 14 wherein said dispersing elements are circumferentially spaced by about 10 micrometers.
16. Apparatus according to any of claims 13-15 and also comprising means for forcing said solid suspended in said liquid between said dispersing elements whereby said solid is subjected to high shear forces and is dispersed in said liquid.
17. Apparatus according to any of the preceding claims wherein said dispersing volume is delimited by retaining elements (32) associated with at least one of said first and second elements.
18. Apparatus according to claim 17 wherein means for supplying and removing includes means for supplying (24) said solid suspended in said liquid to said dispersing volume at a location intermediate said retaining elements.
19. Apparatus according to any of the preceding claims wherein the dispersion of solids in liquid is a lithographic ink.
20. A method for dispersion of solids in liquids comprising the steps of:
 introducing a solid suspended in a liquid into a dispersing volume defined by first and second respective surfaces of first and second relatively movable elements, said volume having disposed therein a multiplicity of dispersing elements; and
 effecting relative movement between said first and second surfaces,
 characterized in that said step of effecting relative movement is operative to impart movement to said dispersing elements mainly by means of hydrodynamic forces created by said relative movement and to subject the solids to high shear forces operative to break up and disperse said solids in said liquid; and
 wherein said dispersing elements form a single layer in said dispersing volume.
21. A method according to claim 20 and further characterized in that said dispersing elements are mutually mechanically unlinked except by hydrodynamic forces.
22. A method according to claim 20 or claim 21 wherein said dispersing elements have a circular cross-section having a diameter which is between 2 and 100 micrometers less than said separation distance.
23. A method according to any of claims 20-22 and further characterized in that said dispersing elements are kept substantially non-contacting with said first and second movable surfaces.
24. A method according to any of claims 20-22 and further characterized in that said dispersing elements are kept substantially non-contacting with said first and second movable surfaces mainly as a result of hydrodynamic forces.
25. A method according to any of claims 20-24 wherein said step of effecting relative movement is operative to cause said dispersing elements to rotate mainly as a result of hydrodynamic forces.
26. A method according to any of claims 20-25 wherein said first and second surfaces are concentrically disposed defining an annular dispersing volume and said dispersing elements are circumferentially closely spaced.
27. A method according to claim 26 wherein said dispersing elements are circumferentially spaced by less than about 25 micrometers.
28. A method according to claim 27 wherein said dispersing elements are circumferentially spaced by about 10 micrometers.
29. A method according to any of claims 26-28 comprising the step of forcing said solid suspended in said liquid between said dispersing elements whereby the solid is subjected to high shear forces and is dispersed in the liquid.
30. A method according to any of claims 20-29 wherein the dispersion of solids in liquid is a



lithographic ink.

Patentansprüche

1. Vorrichtung für eine Dispersion von Feststoffen in Flüssigkeiten, mit
 - a) einem ersten und einem zweiten relativ bewegbaren Element (10, 14; 68, 70) mit jeweils einer ersten und einer zweiten Oberfläche (22, 20) mit einem Trennabstand zwischen diesen, die so angeordnet sind, um ein Dispersions-Volumen (18) dazwischen zu definieren;
 - b) einer Vielzahl von Dispersionselementen (30, 72; 104), die innerhalb des Dispersions-Volumen angeordnet sind;
 - c) einer Einrichtung (24, 100, 102) zum Zuführen eines in einer Flüssigkeit suspendierten Feststoffes in das Dispersions-Volumen und zum Entfernen einer dispergierten Form aus dem in der Flüssigkeit suspendierten Feststoff; und mit
 - d) einer Einrichtung (110, 112) zum Bewirken einer relativen Bewegung zwischen der ersten und der zweiten Oberfläche;

dadurch gekennzeichnet, daß

die Vielzahl der Elemente eine einzelne Schicht in dem Dispersions-Volumen bilden;

den dispergierenden Elementen eine Bewegung erteilt wird, hauptsächlich mit Hilfe von hydrodynamischen Kräften, die durch die relative Bewegung erzeugt werden;

wobei sich die dispergierenden Elemente mit einer Geschwindigkeit bewegen, die sich von der Geschwindigkeit von sowohl der ersten als auch der zweiten Oberfläche unterscheidet;

die Feststoffe hohen Scherkräften ausgesetzt werden, die dazu dienen, die Feststoffe in der Flüssigkeit aufzubrechen und zu dispergieren.
2. Vorrichtung nach Anspruch 1, in der die Vielzahl der dispergierenden Elemente mechanisch wechselseitig entkoppelt sind, ausgenommen durch die hydrodynamischen Kräfte.
3. Vorrichtung nach Anspruch 1 oder nach Anspruch 2, bei der die dispergierenden Elemente einen kreisförmigen Querschnitt haben mit einem Durchmesser, der zwischen 2 und 100 Micrometer kleiner ist als der Trennungsabstand.
4. Vorrichtung nach irgendeinem der vorhergehenden Ansprüche, bei der die dispergierenden Elemente allgemein kugelförmige Elementen

te aufweisen.

5. Vorrichtung nach Anspruch 4, bei der der Trennungsabstand um ca. 5 Micrometer größer ist als der genannte Durchmesser.
6. Vorrichtung nach Anspruch 5, bei der der Trennungsabstand zwischen ca. 20 und 70 Micrometer größer ist als der genannte Durchmesser.
7. Vorrichtung nach irgendeinem der Ansprüche 1-3, bei der die dispergierenden Elemente allgemein zylinderrörmige Elemente aufweisen.
8. Vorrichtung nach Anspruch 7, bei der der Trennungsabstand um ca. 5 Micrometer größer ist als der genannte Durchmesser.
9. Vorrichtung nach Anspruch 8, bei der der Trennungsabstand zwischen ca. 10 und 25 Micrometer größer ist als der genannte Durchmesser.
10. Vorrichtung nach irgendeinem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß die dispergierenden Elemente im wesentlichen außer Berührung mit der ersten und der zweiten bewegbaren Fläche gehalten sind.
11. Vorrichtung nach irgendeinem der Ansprüche 1-10, dadurch gekennzeichnet, daß die dispergierenden Elemente im wesentlichen berührungsfrei von der ersten und der zweiten bewegbaren Oberfläche, hauptsächlich auf Grund der hydrodynamischen Kräfte gehalten sind.
12. Vorrichtung nach irgendeinem der vorhergehenden Ansprüche, bei der die Einrichtung zum Bewirken einer relativen Bewegung dafür ausgebildet ist, die dispergierenden Elemente hauptsächlich als Ergebnis der hydrodynamischen Kräfte zu einer Drehung zu veranlassen.
13. Vorrichtung nach irgendeinem der vorhergehenden Ansprüche, bei der die erste und die zweite Oberfläche konzentrisch angeordnet sind und ein ringförmiges Dispersions-Volumen definieren und wobei die dispergierenden Elemente umfangsmäßig dicht beabstandet sind.
14. Vorrichtung nach Anspruch 13, bei der die dispergierenden Elemente umfangsmäßig um weniger als ca. 25 Micrometer beabstandet sind.



15. Vorrichtung nach Anspruch 14, bei der die dispergierenden Elemente umfangsmäßig um ca. 10 Micrometer beabstandet sind.
16. Vorrichtung nach irgendeinem der Ansprüche 13-15, mit einer Einrichtung zum Zwingen des in der Flüssigkeit suspendierten Feststoffes zwischen die dispergierenden Elemente, wodurch der Feststoff hohen Scherkräften ausgesetzt wird und in der Flüssigkeit dispergiert wird.
17. Vorrichtung nach irgendeinem der vorhergehenden Ansprüche, bei der das Dispersions-Volumen durch Rückhalteelemente (32) begrenzt ist, die wenigstens einem der ersten und zweiten Elemente zugeordnet sind.
18. Vorrichtung nach Anspruch 17, bei der die Einrichtung zum Zuführen und Entfernen eine Vorrichtung enthält, um den in der Flüssigkeit suspendierten Feststoff in das Dispersions-Volumen an einer Stelle zwischen den Rückhalteelementen zuzuführen (24).
19. Vorrichtung nach irgendeinem der vorhergehenden Ansprüche, bei der die Dispersion der Feststoffe in der Flüssigkeit eine lithographische Tinte ist.
20. Verfahren zum Dispergieren von Feststoffen in Flüssigkeiten mit den folgenden Schritten:
 einführen eines in einer Flüssigkeit suspendierten Feststoffes in ein Dispersions-Volumen, welches durch eine erste und eine zweite jeweilige Oberfläche eines ersten und eines zweiten relativ bewegbaren Elements definiert ist, wobei in dem Volumen eine Vielzahl von dispergierenden Elementen angeordnet sind; und
 bewirken einer relativen Bewegung zwischen der ersten und der zweiten Oberfläche, dadurch gekennzeichnet, daß der Schritt gemäß des Herbeiführens einer relativen Bewegung so ausgeführt wird, daß den dispergierenden Elementen hauptsächlich mit Hilfe von hydrodynamischen Kräften eine Bewegung erteilt wird, die durch die relative Bewegung erzeugt werden und daß die Feststoffe hohen Scherkräften unterworfen werden, die ein Aufbrechen und ein Dispergieren der Feststoffe in der Flüssigkeit bewirken; und
 wobei die dispergierenden Elemente eine einzelne Schicht in dem Dispersions-Volumen formen.
21. Verfahren nach Anspruch 20, dadurch gekennzeichnet, daß die dispergierenden Elemente wechselseitig mechanisch nicht verkoppelt sind, ausgenommen durch hydrodynamische Kräfte.
22. Verfahren nach Anspruch 20 oder Anspruch 21, bei dem die dispergierenden Elemente einen kreisförmigen Querschnitt aufweisen mit einem Durchmesser, der zwischen 2 und 100 Micrometer kleiner ist als der Trennungsabstand.
23. Verfahren nach irgendeinem der Ansprüche 20-22, dadurch gekennzeichnet, daß die dispergierenden Elemente im wesentlichen in einem Nichtberührungszustand mit den ersten und zweiten bewegbaren Oberflächen gehalten werden.
24. Verfahren nach irgendeinem der Ansprüche 20-22, dadurch gekennzeichnet, daß die dispergierenden Elemente im wesentlichen in einem Nichtberührungszustand mit der ersten und der zweiten bewegbaren Oberfläche hauptsächlich als Ergebnis der hydrodynamischen Kräfte gehalten werden.
25. Verfahren nach irgendeinem der Ansprüche 20-24, bei dem der Schritt der Hervorbringung einer relativen Bewegung so ausgeführt wird, daß die dispergierenden Elemente veranlaßt werden, sich hauptsächlich als Ergebnis der hydrodynamischen Kräfte zu drehen.
26. Verfahren nach irgendeinem der Ansprüche 20-25, bei dem die erste und die zweite Oberfläche konzentrisch angeordnet sind und ein ringförmiges Dispersionsvolumen definieren, wobei die dispergierenden Elemente umfangsmäßig dicht beabstandet sind.
27. Verfahren nach Anspruch 26, bei dem die dispergierenden Elemente um weniger als ca. 25 Micrometer umfangsmäßig beabstandet sind.
28. Verfahren nach Anspruch 27, bei dem die dispergierenden Elemente um ca. 10 Micrometer umfangsmäßig beabstandet sind.
29. Verfahren nach irgendeinem der Ansprüche 26-28, wonach der in der Flüssigkeit suspendierte Feststoff zwischen die dispergierenden Elemente gezwungen wird, wodurch der Feststoff hohen Scherkräften ausgesetzt wird und in der Flüssigkeit dispergiert wird.
30. Verfahren nach irgendeinem der Ansprüche 20-29, bei dem die Dispersion der Feststoffe in der Flüssigkeit eine lithographische Tinte ist.



Revendications

1. Appareil pour la dispersion de solides dans des liquides, comprenant :
 - (a) des premier et second éléments relativement mobiles (10, 14 ou 68, 70) comportant des première et seconde surfaces respectives (22, 20) présentant entre elles une distance une distance de séparation et disposées de manière à définir entre elles un volume de dispersion (18) ;
 - (b) une multiplicité d'éléments de dispersion (30, 72 ou 104) disposés à l'intérieur du volume de dispersion ;
 - (c) des moyens (24, 100, 102) pour amener une matière solide en suspension dans un liquide jusqu'au volume de dispersion et pour extraire sous une forme dispersée ladite matière solide en suspension dans le liquide ; et
 - (d) des moyens (110, 112) pour créer un mouvement relatif entre lesdites première et seconde surfaces ;

caractérisé en ce que :

la multiplicité d'éléments forme une seule couche dans ledit volume de dispersion ;

un mouvement est communiqué aux éléments de dispersion principalement au moyen de forces hydrodynamiques créées par le mouvement relatif ;

les éléments de dispersion se déplacent à une vitesse différente de la vitesse à la fois de la première et de la seconde surfaces ; et

les solides sont soumis à des forces de cisaillement élevées agissant de manière à rompre et à disperser les matières solides dans le liquide.
2. Appareil selon la revendication 1, dans lequel la multiplicité des éléments de dispersion sont désaccouplés mutuellement par voie mécanique sauf par des forces hydrodynamiques.
3. Appareil selon la revendication 1 ou la revendication 2, dans lequel lesdits éléments de dispersion ont une section transversale circulaire dont le diamètre est de 2 à 100 micromètres inférieur à ladite distance de séparation.
4. Appareil selon l'une quelconque des revendications précédentes, dans lequel lesdits éléments de dispersion comprennent des éléments sphériques d'une façon générale.
5. Appareil selon la revendication 4, dans lequel ladite distance de séparation est supérieure à 5 micromètres audit diamètre.
6. Appareil selon la revendication 5, dans lequel ladite distance de séparation est supérieure d'environ 20 à 70 micromètres audit diamètre.
7. Appareil selon l'une quelconque des revendications 1-3, dans lequel lesdits éléments de dispersion comprennent des éléments cylindriques d'une façon générale.
8. Appareil selon la revendication 7, dans lequel ladite distance de séparation est supérieure d'environ 5 micromètres audit diamètre.
9. Appareil selon la revendication 8, dans lequel ladite distance de séparation est supérieure d'environ 10 à 25 micromètres audit diamètre.
10. Appareil selon l'une quelconque des revendications précédentes et **caractérisé**, en outre, en ce que lesdits éléments de dispersion sont maintenus sensiblement hors de contact avec lesdites première et seconde surfaces mobiles.
11. Appareil selon l'une quelconque des revendications 1-10 et **caractérisé**, en outre, en ce que lesdits éléments de dispersion sont maintenus sensiblement hors de contact avec lesdites première et seconde surfaces mobiles principalement par suite des forces hydrodynamiques.
12. Appareil selon l'une quelconque des revendications précédentes, dans lequel lesdits moyens pour créer un mouvement relatif agissent de manière à faire tourner lesdits éléments de dispersion principalement par suite des forces hydrodynamiques.
13. Appareil selon l'une quelconque des revendications précédentes, dans lequel lesdites première et seconde surfaces sont disposées concentriquement en définissant un volume de dispersion annulaire et lesdits éléments de dispersion sont espacés étroitement de façon circconférencielle.
14. Appareil selon la revendication 13, dans lequel lesdits éléments de dispersion sont espacés circconférenciellement de moins de 25 micromètres environ.
15. Appareil selon la revendication 14, dans lequel lesdits éléments de dispersion sont espacés circconférenciellement d'environ 10 micromètres.



16. Appareil selon l'une quelconque des revendications 13-15 et comprenant également des moyens pour refouler ladite matière solide en suspension dans ledit liquide entre lesdits éléments de dispersion, grâce à quoi ladite matière solide est soumise à des forces de cisaillement élevées et est dispersée dans ledit liquide.
17. Appareil selon l'une quelconque des revendications précédentes, dans lequel ledit volume de dispersion est délimité par des éléments de retenue (32) associés à au moins un desdits premier et second éléments.
18. Appareil selon la revendication 17, dans lequel les moyens d'amenée et d'extraction comprennent des moyens pour amener (24) lesdites matières solides en suspension dans le liquide jusqu'audit volume de dispersion à un endroit situé entre lesdits éléments de retenue.
19. Appareil selon l'une quelconque des revendications précédentes, dans lequel la dispersion de matières solides dans un liquide est une encre lithographique.
20. Procédé pour la dispersion de matières solides dans des liquides, comprenant les étapes consistant :
à introduire une matière solide en suspension dans un liquide dans un volume de dispersion défini par les première et seconde surfaces respectives de première et second éléments mobiles de façon relative, une multiplicité d'éléments de dispersion étant disposés dans ledit volume ; et
à créer un mouvement relatif entre lesdites première et seconde surfaces,
caractérisé en ce que ladite étape consistant à créer un mouvement relatif a pour effet de communiquer un mouvement auxdits éléments de dispersion principalement au moyen des forces hydrodynamiques créées par ledit mouvement relatif et de soumettre les matières solides à des forces de cisaillement élevées agissant de manière à rompre et à disperser lesdites matières solides dans ledit liquide ; et
en ce que lesdits éléments de dispersion forment une seule couche dans ledit volume de dispersion.
21. Procédé selon la revendication 20 et **caractérisé**, en outre, en ce que lesdits éléments de dispersion ne sont pas liés mutuellement de façon mécanique sauf par des forces hydrodynamiques.
22. Procédé selon la revendication 20 ou la revendication 21, dans lequel lesdits éléments de dispersion ont une section transversale circulaire d'un diamètre qui est inférieur de 2 à 100 micromètres à ladite distance de séparation.
23. Procédé selon l'une quelconque des revendications 20-22 et **caractérisé**, en outre, en ce que lesdits éléments de dispersion sont maintenus de façon sensiblement hors de contact avec lesdites première et seconde surfaces mobiles.
24. Procédé selon l'une quelconque des revendications 20-22 et **caractérisé**, en outre, en ce que lesdits éléments de dispersion sont maintenus sensiblement hors de contact avec lesdites première et seconde surfaces mobiles principalement par suite des forces hydrodynamiques.
25. Procédé selon l'une quelconque des revendications 20-24, dans lequel ladite étape de création de mouvement relatif a pour effet de faire tourner lesdits éléments de dispersion principalement par suite des forces hydrodynamiques.
26. Procédé selon l'une quelconque des revendications 20-25, dans lequel lesdites première et seconde surfaces sont disposées concentriquement en définissant un volume de dispersion annulaire et lesdits éléments de dispersion sont espacés étroitement circonférentiellement.
27. Procédé selon la revendication 26, dans lequel lesdits éléments de dispersion sont espacés circonférentiellement de moins de 25 micromètres environ.
28. Procédé selon la revendication 27, dans lequel lesdits éléments de dispersion sont espacés circonférentiellement d'environ 10 micromètres.
29. Procédé selon l'une quelconque des revendications 26-28, comprenant l'étape consistant à refouler ladite matière solide en suspension dans ledit liquide entre lesdits éléments de dispersion, grâce à quoi la matière solide est soumise à des forces de cisaillement élevées et est dispersée dans le liquide.
30. Procédé selon l'une quelconque des revendications 20-29, dans lequel la dispersion de matières solides dans un liquide est une encre.



lithographique.

5

10

15

20

25

30

35

40

45

50

55

13

