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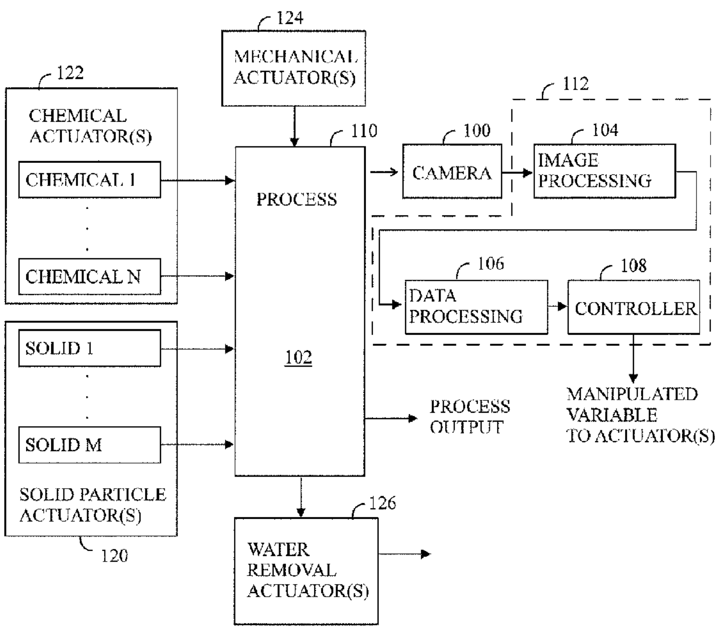
(54) Titre : APPAREIL ET PROCEDE DE MESURE DE SUSPENSION ET DE COMMANDE DE PROCESSUS DE SUSPENSION

(54) Title: APPARATUS AND METHOD FOR MEASURING SUSPENSION AND CONTROLLING PROCESS OF SUSPENSION



(57) Abrégé/Abstract:
An apparatus for measuring suspension comprises an image capturing device for capturing at least one measurement image of the suspension, the at least one measurement image presenting at least one solid particle; an information processing unit which receives the at least one measurement image and determines a state of attachment of the solid particles of the suspension to each other on the basis of pattern recognition applied to the at least one measurement image. The information processing unit determines, on the basis of the state of the attachment of the solid particles of the suspension, suspension data associated with at least one of the following: at least one process control chemical, at least one fiber property, at least one fines property, a relation between solid particles of different sizes, formation, and water content.

(57) Abstract

An apparatus for measuring suspension comprises an image capturing device for capturing at least one measurement image of the suspension, the at least one measurement image presenting at least one solid particle; an information processing unit which receives the at least one measurement image and determines a state of attachment of the solid particles of the suspension to each other on the basis of pattern recognition applied to the at least one measurement image. The information processing unit determines, on the basis of the state of the attachment of the solid particles of the suspension, suspension data associated with at least one of the following: at least one process control chemical, at least one fiber property, at least one fines property, a relation between solid particles of different sizes, formation, and water content.

(Figure 1)

Apparatus and method for measuring suspension and controlling process of suspension

Field

The invention relates to an apparatus and method for measuring suspension and controlling process of suspension.

Background

Dosing paper machine wet end chemicals has typically been based on conventional wet-end chemistry measurements by a charge analyzer, a conductivity meter, a pH meter or the like. Additionally, the dosing of the process control chemicals may depend on measurements of paper properties and paper machine runnability. The assumed effect of the process control chemicals on the process is based on laboratory studies and theories which are actually not well correlated with the effect in real industrial processes. This is why a controller of paper machine doesn't actually have information about the state of the process, and thus cannot determine whether the process is at, close to or far from the optimum. Laboratory testing for checking the system performance is also performed rather seldom.

Water removal is another critical parameter of a paper manufacturing process. However, this information is normally available through pulp freeness measurements and later on from machine water removal measurements which are too late for the ideal determination of the state of a process.

Due to the facts, process machines often end up in situations far from optimal. This may lead to overdosing of the process control chemicals which is a problem to the environment. Additionally, overdosing and/or wrong water removal information may cause a runnability problem and deteriorate the quality of the end product.

Hence, there is a need to improve the measurements and the control.

Brief description

The present invention seeks to provide an improvement in the measurements. According to an aspect of the present invention, there is provided an apparatus for measuring suspension.

According to another aspect of the present invention, there is provided an apparatus for controlling a process of suspension.

According to another aspect of the present invention, there is provided a method for a process associated with suspension including solid particles.

The invention has advantages. The measurement of attachment of fibers together on the basis of images leads to savings in chemical use and drainage and retention can be optimized. The measurement also makes it possible to determine real time water removal, for example, from a headbox and increase controllability of the process.

List of drawings

Example embodiments of the present invention are described below, by way of example only, with reference to the accompanying drawings, in which

Figure 1 illustrates an example of apparatus for measuring suspension;

Figure 2A illustrates an example of a measurement image of suspension;

Figure 2B illustrates an example of a fraction including the largest solid particles of four fractions having no process control chemical;

Figure 2C illustrates an example of a fraction including the second largest solid particles of the four fractions having no process control chemical;

Figure 2D illustrates an example of a fraction including the third largest solid particles of the four fractions having no process control chemical;

Figure 3A illustrates an example of a fraction including the largest solid particles of four fractions having at least one process control chemical;

Figure 3B illustrates an example of a fraction including the second largest solid particles of the four fractions having at least one process control chemical;

Figure 3C illustrates an example of a fraction including the third largest solid particles of the four fractions having at least one process control chemical;

Figure 3D illustrates an example of a fraction including the smallest solid particles of the four fractions having at least one process control chemical;

Figure 4 illustrates an example of a block chart of at least one processor and at least one memory;

Figure 5 illustrates an example of a dilution sub-process;

Figure 6 illustrates an example of a fractionator;

Figure 7 illustrates an example of fiber widths without process control chemicals and with eleven different process control chemicals;

Figure 8 illustrates an example of sizes of large and small flocs without process control chemicals and under the effect of eleven different process control chemicals;

Figure 9 illustrates an example of sizes of fines and fillers flocs without process control chemicals and under the effect of eleven different process control chemicals;

Figure 10 illustrates an example of distributions of solid particle sizes in five fractions without process control chemicals and under the effect of eleven different process control chemicals;

Figure 11 illustrates an example of a paper machine; and

Figure 12 illustrates of an example of a flow chart of a measuring method of suspension.

Description of embodiments

The following embodiments are only examples. Although the specification may refer to “an” embodiment in several locations, this does not necessarily mean that each such reference is to the same embodiment(s), or that the feature only applies to a single embodiment. Single features of different embodiments may also be combined to provide other embodiments. Furthermore, words "comprising" and "including" should be understood as not limiting the described embodiments to consist of only those features that have been mentioned and such embodiments may contain also features/structures that have not been specifically mentioned.

It should be noted that while Figures illustrate various embodiments, they are simplified diagrams that only show some structures and/or functional entities. The operational connections shown in the Figures may refer to logical or physical connections. It is apparent to a person skilled in the art that the described apparatus may also comprise other functions and structures than those described in Figures and text. It should be appreciated that details of some functions, structures, and the signalling used for measurement and/or controlling are irrelevant to the actual invention. Therefore, they need not be discussed in more detail here.

Figure 1 illustrates an example of an apparatus for measuring suspension 102. The suspension 102 has water as medium which has minute solid particles dispersed within the medium of water. The solid particles are separate from each other but they may aggregate together. However, the aggregates or flocks may then, in turn, become solid particles and be separate flocks. The fact that the solid particles are separate, means that they have a physical distance therebetween. The solid particles may include at least one of the following: fibers; fines; fillers, minerals; solids of sewage; any combination thereof or the like. The suspension 102 may be paper stock, sewage water or suspension of a mineral process, for example. The fibers may be natural fibers, such as plant fibers or animal fibers, or synthetic fibers. Additionally, the solid particles may include fines, fillers and/or at least one kind of process control chemical. The one kind of process control chemical may be an aggregating additive or a flocculating agent, for example, which makes the solid particles to combine in flocks, flocculates, aggregates or clusters.

An image capturing device 100 captures at least one measurement image 200 (examples of the images are shown in Figure 2A to 3D) of the suspension 102. An example of the measurement image 200 is shown in Figure 2. The measurement image of Figure 2A shows wood fibers and fines as the solid particles 202. There may also be fillers. Additionally, the measurement image of suspension 102 shown in Figure 2A may also include at least one process control chemical. One of the wood fibers is a vessel which is much thicker than the other fibers. The at least one measurement image 200 may refer to one or more still image. The at least one image may also refer to video images. The image capturing device 100 may comprise one or more cameras (note that Figure 1 shows only one camera). The at least one camera may be a high-definition camera. The camera may be a charge-couple device (CCD) camera or a complementary metal oxide semiconductor (CMOS) camera, for example. In an embodiment, the at least one camera may be a visually visible light camera. In an embodiment, the at least one camera may be an infra-red camera. In an embodiment, the at least one camera may be an ultraviolet camera. In an embodiment, the image capturing device 100 may include any combination of the visually visible light camera, the infra-red camera, and the ultraviolet camera. The ratio between the largest resolvable or detectable object in the measurement image and the smallest resolvable object in the measurement image of the image capturing device 100 may be 1000000:1 or higher, for example. For determining the ratio, it may be assumed that the largest resolvable or detectable object fills the whole image area of the image capturing device 100 while the smallest resolvable object has the size of one pixel. That is, the ratio between the largest resolvable or detectable object in the measurement image and the smallest resolvable object in the measurement image is Pmax:1, where Pmax is the maximum number of pixels of the measurement image.

An information processing unit 112 then receives the at least one measurement image 200 and determines a state of attachment of the solid particles 202 of the suspension 102 to each other. The determination of the state of attachment of the solid particles 202 to each other may be performed using at least one pattern recognition algorithm applied to the at least one measurement image 200. The attachment of solid particles 202 to each other may result in a flock or a floccule both of which are loose or dense aggregates of the solid particles of the suspension 102.

The information processing unit 112 may be implemented as a processor and software. Likewise, the information processing unit 112 can alternatively be implemented in the form of a hardware configuration by means of separate logic components or one or more Application-Specific Integrated Circuits (ASIC). Also a hybrid of these different implementations is possible.

The information processing unit 112 determines, on the basis of the state of the attachment of the particles 202 of the suspension 102, suspension data associated with at least one of the following: at least one process control chemical, a fiber property, a fines property, a relation between particles of different sizes, formation, and water content. The suspension data related to the at least one process control chemical may refer to an amount of at least one process control chemical. Here the term content refers to a proportion of the named substance in the suspension 102. Additionally, the information processing unit 112 may determine a fiber type content, stock type content, and/or water removal potential for example. The information processing unit 112 may comprise an image processing sub-unit 104, which determines the state of attachment of the solid particles 202 together on the basis of pattern recognition applied to the at least one measurement image 200 (see Figure 2A). Furthermore, the information processing unit 112 may comprise a data processing sub-unit 106 which determines the suspension data associated with at least one of the following: at least one process control chemical, fiber content, fines content, stock type content, relation between particles of different sizes, and water content.

The suspension data associated with the amount of at least one process control chemical may refer to an amount of the at least one process control chemical present in the suspension 102 or an amount of the at least one process control chemical to be added in the suspension 102.

The suspension data associated with the fiber property may refer to an amount of the fiber content present in the suspension 102 or an amount of the fibers to be added in the suspension 102.

The suspension data associated with the fiber property may refer to a quality of the fiber present in the suspension 102 or a quality of the fibers to be added in the suspension 102.

The suspension data associated with the fiber property may refer to a type of the fiber present in the suspension 102 or a type of the fibers to be added in the suspension 102.

The suspension data associated with the fines property may refer to an amount of the fines present in the suspension 102 or an amount of the fines to be added in the suspension 102. The fines property may also be understood as fines and filler property.

The suspension data associated with the fines property may refer to a size or a size distribution of the fines present in the suspension 102 or a size or a size distribution of the fines to be added in the suspension 102.

The suspension data associated with the stock type content may refer to an amount of the stock type present in the suspension 102 or an amount of the stock type to be added in the suspension 102. The suspension 102 may include one paper stock type or the suspension 102 may include a plurality of paper stock types. A stock type refers to a tree, in general a fiber source or even more generally a particle source from which the stock has been made of and/or to the manufacturing method of the stock. In general, the stock may be manufactured using chemical processing or mechanical processing. Additionally or alternatively, a stock may have recycled or non-recycled fibers. The recycled fibers, in turn, vary largely in stock types. A fiber type of a paper stock may determine the stock type.

In an embodiment, the information processing unit 112 may determine, on the basis of the state of the attachment of the particles 202 of the suspension 102, the suspension data associated with at least one of the following: deviation of the amount of at least one process control chemical from a chemical reference or from a chemical target, deviation of the fiber property from a fiber reference or from a fiber target, deviation of the fines property from a fines reference or from a fines target, deviation of the stock type content from a stock type reference or from a stock type target, deviation of the relation between particle of different sizes from a particle reference or from a particle target, deviation of flocking from a flocking reference or from flocking target, and deviation of the water content from a water reference or from a water target. These targets refer to set-point values of the suspension 102. The target may mean a set-point of the process 110 which itself refers to a desired value of a controlled variable.

Figures 2B to 2E illustrate examples of four reference fractions of the suspension 102 which have no aggregating additives i.e. process control chemicals. In general, the solid particles 202 without process control chemicals may represent solid particle references for the measurement. In Figure 2B there are the largest solid particles 202 and thus the solid particles 202 of Figure 2B may represent a first fiber reference. Figure 2C has the second largest particles 202. Also the solid particles 202 in this figure may represent a second fiber reference, for example. Figure 2D has the third largest particles. The solid particles 202 in this figure may represent a solid particle reference somewhere between fibers and fines, for example. Figure 2E has the smallest particles which may mainly include fines and/or fillers. The solid particles 202 in this figure may represent a fines reference, for example. The fines reference may also be considered a fines and fillers reference.

In an embodiment, the deviation of the amount of at least one process control chemical from a chemical reference may be determined by comparing the state of attachment of the solid particles 202 to each other in a measurement image with a state of attachment of solid particles to each other in a reference image. The reference images, with which the image of the suspension 102 is compared, may have the same particle content and the same kind of particles with varying amount of the same process control chemical or chemicals, the amount of the process control chemical or chemicals being known. The reference image which has a highest correlation or similarity with the measurement image of the suspension 102 may be used to determine the amount of the at least one process control chemical present in the solution 102 or the amount of the at least one process control chemical to be added in the solution 102. The correlation C(τ), which measures similarity between objects, may mathematically be calculated for variables x(t) and y(t) in the following manner, for example:

$$C(t) = \int_a^b x(\tau)y(\tau + t)d\tau ,$$

where a and b represent the calculation period of the correlation. Digitally, correlation row **C** may be calculated as a cross product for sequences **X** and **Y** in the following manner:

$$C(n) = \sum_{i=1}^{N} x(i)y(n+i) ,$$

where each C(n) corresponds to an element of correlation row **C**.

Figures 3A to 3D illustrate examples of four fractions of the suspension 102 which have at least one process control chemical. The process control chemical in this case is polymer and silica as a flocking agent. Figures 3A to 3D may illustrate examples of measurement images of a suspension 102, the state of which is to be determined. Alternatively, Figures 3A to 3D may be considered to illustrate examples of target images, which have the target or set-point values of the solid particles 202. Although Figures 3A to 3D show suspensions including wood fibers and fines&fillings, suspensions including mineral particles or sewage including solid particles from domestic households, agriculture and/or industry may form aggregates or clusters from the solid particles in the presence of process control chemicals.

In Figure 3A there are the largest solid particles 202 and the measurement image of Figure 3A may be compared with the fiber reference Figure 2B. Figure 3B has the second largest particles 202, and the measurement image of Figure 3B may be compared with the fiber reference image of Figure 2C. Figure 3C has the third largest particles 202, and the measurement image of Figure 3C may be compared with the solid particle reference image of Figure 2D. Figure 3D has the smallest particles 202, and the measurement image of Figure 3D may be compared with the fines reference image of Figure 2E. According to this kind of comparison the deviation indicates how much effect at least one aggregate additive has had on the suspension 102.

In an embodiment, the deviation of the fiber property from the fiber reference may refer to a deviation of the fiber type from a fiber type reference. In an embodiment, the deviation of the fiber property from the fiber target may refer to a deviation of the fiber type from a fiber type target. The fiber type may be based on fiber length, fiber thickness, ratio of fiber length and thickness, fiber curliness, thickness of the wall of a fiber, branching of a fiber, any combination thereof or the like.

The length of a fiber may be determined on the basis of a length of a midline in the image of the fiber. The curliness C of an object can be defined, for example, by means of the following equation:

$$C = 100 \cdot (1 - \delta/l),$$

where δ is the shortest distance between the fiber of an object and l is the length of the midline of the object. The thickness of a fiber may be determined on the basis of a length between outer surface of the fiber in a perpendicular direction to the midline in the image of the fiber. The thickness of a fiber wall may be determined on the basis of a length from the midline to the outer surface of the fiber in the perpendicular direction to the midline in the image of the fiber. These measurement principles can be applied to any kind, shape or form of solid particles, not only fibers. An image processing algorithm can perform the required operations and form these values.

In an embodiment, the information processing unit 112 may determine data associated with a zeta potential value of the suspension directly or indirectly on the basis of the suspension data. When a value of the zeta potential is below zero, flocculation may continue and the at least one process control chemical may be input to the suspension in order to have more flocks, make particles thicker, or increase the size of flocks. When a value of the zeta potential is at zero, flocculation comes to an end, and an increase in the at least one process control chemical will not provide more flocks or increase the size of flocks.

The at least one process control chemical may be input gradually in the suspension 102, and the state of the attachment of the solid particles 202 to each other may be determined as a function of the gradual increase of the at least one process control chemical. The input may be performed in a discrete manner or in a continuous manner. By observing from the at least one image that the latest addition of the at least one process control chemical doesn't cause a change in the state of the attachment of the solid particles 202 to each other, the information processing unit 112 may determine that the zeta potential has reached the value 0. The zeta potential may actually have crossed the zero value somewhat, but still a huge overdose may be avoided.

On the other hand, by observing from the at least one image that the latest addition of the at least one process control chemical causes a change in the state of the attachment of the solid particles 202 to each other, the information processing unit 112 may determine that the zeta potential has not yet reached the value 0. That may be a reason to continue the addition of the at least one process control chemical. By observing a speed at which the state of the attachment of the solid particles 202 to each other develops with respect to the addition of the at least one process control chemical, the information processing unit 112 may determine a value of the zeta potential.

The zeta potential is an electrokinetic potential in the suspension. The zeta-potential thus refers to ionic concentration and a difference in electric potential as a function of distance from a solid particle 202 in the suspension 102.

The zeta-potential is formed because charged solid particles of the same charge gather around a solid particle 202. When the electric repulsion of the charged solid particles 202 of the same charge is the same as the attraction towards the solid particle 202, no more charged solid particles will gather around the solid particle 202. At this point, the value of the zeta potential is zero. The phenomenon can be seen or detected in the captured images. A fiber attracts a certain number of smaller solid particles 202 such as fines and/or fillers around it. The fibers or other large solid particles also attract each other which results in flocks. A flocculating agent may increase the number of smaller solid particles 202 around the fiber but inevitably there is a certain limit. The length and thickness of the fiber seems to increase when smaller solid particles 202 are attached to the fiber. A flocculating agent also increases the number of flocks and/or the size of the flocks. One flocculating agent may have a different effect on the zeta potential than another flocculating agent. A suspension 102 with a high zeta-potential is electrically less attracting and thus such a suspension has no flocks, few flocks or only small flocks. A suspension 102 with a low zeta-potential is electrically more attracting and thus such a suspension has flocks. The lower the zeta potential is, the more flocculates or flocks there are, and vice versa.

In an embodiment, the deviation of the amount of at least one process control chemical from a chemical target may be determined by comparing the state of attachment of the solid particles 202 to each other in a measurement image with a state of attachment of the particles 202 to each other in a target image. The target image shows a set-point condition for the suspension 102. The target images, which may be similar to those in Figures 3A to 3D and with which the measurement image of the suspension 102 is compared, may have the same particle content and the same kind of solid particles with varying amount of the same process control chemical or chemicals, the amount of the process control chemical or chemicals being known. The deviation in a correlation between the measurement image of the suspension 102 and the target image may be used to determine the amount of the at least one process control chemical present in the solution 102 or the amount of the at least one process control chemical to be added in the solution 102. According to this kind of comparison the deviation indicates how much the at least one process control chemical should change the present condition of the suspension 102.

In an embodiment, the information processing unit 112 may comprise an artificial neural network which may determine the suspension data on the basis of supervised or non-supervised pre-training of the pattern recognition.

In the supervised classification, the information processing unit 112 is manually taught to distinguish different solid particles and classify them in different classes.

The pattern recognition of the non-supervised neural network may use, for instance, a self-organizing map (SOM) of neural computing.

In an embodiment, the information processing unit 112 may classify and organize automatically and in a unsupervised or supervised manner the images on the basis of at least one clustering algorithm. The unsupervised classification may automatically organize the images on the basis of at least one of the following: self-organizing map of neural computing, t-distributed stochastic neighbor embedding, principal component analysis, sammon mapping method, GTM (General Topographic Mapping), LLE (Locally Linear Embedding) mapping, Isomap, agglomerative or hierarchial hierarchal clustering, including single-link-, complete-link-, average-link clustering, clustering error minimization, distance error minimization, K-means clustering, K-method, and graph-based methods like single-or complete link clustering, density based method, density-based spatial cluster of applications with noise (DBSCAN), AUTOCLASS, SNOB, BIRCH, MCLUST, or model based clustering COBWEB or CLASSIT, simulated annealing for clustering, genetic algorithms, Bayesian method, Kernel method, Multidimensional scaling, principal curve, T-SNE, some of their combination or the like.

In an embodiment, the processing unit 112 using unsupervised classification or supervised classification may optimize the number of predetermined features measured from the images. The optimization of the features may be automatized or it may require a user input.

In an embodiment an example of which is illustrated in Figure 4, the information processing unit 112 may comprise one or more processors 400 and one or more memories 402. The one or more memories 402 may include a computer program code. The one or more memories 402 and the computer program code may cause, with the one or more processors 400, the apparatus to perform the following steps. Pattern recognition is performed to the measurement image 200 on the basis of at least one pattern recognition algorithm. The state of the attachment of the particles 202 of the suspension 102 to each other is determined on the basis of the pattern recognition. On the basis of the state of the attachment of the particles 202 of the suspension 200, the suspension data is determined. The comparison between the reference image and the measurement image or the comparison between the target image and the measurement image may also be performed with the one or more processors 400, the one or more memories 402 and the computer program code.

In an embodiment, an example of which is illustrated in Figure 5, the apparatus may comprise a dilution sub-process 500. The dilution sub-process 500 may take a sample from the process 110, dilute the sample to a desired consistency range or to a desired consistency with water, and provide, for the image capture performed by the image capturing device 100, the diluted sample of the suspension 102. The dilution sub-process 500 may comprise a sampler 502 which takes a suspension sample from the process 110. The sampler 502 may comprise a valve the operation of which may be controlled by the information processing unit 112. The dilution sub-process 500 may also comprise a measurement chamber 504. The sample may flow through the measurement chamber 504 or the measurement chamber 504 may be a closed container which may be emptied back to the process 110 or elsewhere. The measurement chamber 504 is transparent to the optical radiation with which the measurement image is captured with the image capturing device 100. The whole measurement chamber 504 may be transparent for capture of image and for potential illumination from a light source 506. Alternatively, the measurement chamber 504 may be sectionally transparent i.e. the measurement chamber 504 may have a window through which the measurement image is captured and potentially illuminated by the light source 506. The reference image and the target image may also be captured similarly.

In an embodiment, an example of which is illustrated in Figure 6, the dilution sub-process 500 may comprise a fractionator 600 which may provide at least one fraction which includes a desired size range of the solid particles 202 of the suspension 102 for the image capture by the image capturing device 100. The fractionator may have a tube for fractionating the solid particles of the suspension 102 flowing in the tube. The image capturing device 100 may capture images directly from the tube which then acts as the measurement chamber. Additionally or alternatively, different fractions may be separated in different containers 602, 604, 606, 608. One or more of the fractions may then be fed from the containers 602 to 608 in to the separate measurement chamber 504 and the image capturing device 100 may then capture an image of the one or more fractions. In an embodiment, at least two fractions from the suspension 102 are formed.

In an embodiment, the information processing unit 112 may determine, on the basis of the states of the attachment of the particles 202 in a plurality of fractions of the suspension 102, the suspension data. By observing from the at least one image that the latest addition of the at least one process control chemical causes a change in the state of the attachment of the solid particles 202 to each other in one or more fractions, the information processing unit 112 may determine that the zeta potential has not yet reached the value 0. For example, it may be more informative to monitor the state of fines fraction than a fiber fraction in some cases because the development in the fines fraction may be faster (there may be more fines particles than fiber particles in a unit volume). That may be a reason to continue the addition of the at least one process control chemical.

The information processing unit 112 may also control on the basis of said suspension data whether to increase, keep unchanged or change a property related to one of the following in the process: process control chemical, fibers, fines, stock type, particles of one size with respect to particles of at least one other size, formation, and water. The information processing unit 112 may also control whether to increase, keep unchanged, decrease or increase one of the following in the process: the process control chemical, the fibers, the fines, the stock type, the particles of one size with respect to particles of at least one other size, and water.

In an embodiment, the information processing unit 112 may control the input of the at least one process control chemical to the process 110 using solid particle actuators 120. Each solid particle actuator SOLID 1 ... SOLID M of the solid particle actuators 120 may feed one kind of solid particles 202 to the process 110. The solid particles 202 of one actuator 120 may differ from the solid particles 202 of at least one other actuator 120. The solid particles may differ from each other on the basis of length, thickness, wall thickness, a type of stock or the like.

In an embodiment, the information processing unit 112 may control the solid particle actuator SOLID 1 ... SOLID M which input of at least two types of stock to the process 110, where M is an integer equal to or larger than one. The type of stocks may differ from each other on the basis of recycling, for example. One of the types of stocks may be recycled stock and another type of stock may be non-recycled stock, for example.

In an embodiment, the information processing unit 112 may control at least one chemical actuator 122 which inputs the at least one flocculant for optimizing flocking of the particles in the process 102. If there are more than one chemical actuator CHEMICAL 1 ... CHEMICAL N in use, one of the process control chemical may differ from at least one other process control chemical, where N is an integer equal to or larger than one,. The process control chemical may refer to a flocculant or a flocculating agent. The purpose of the at least one flocculant as the process control chemical is to cause the solid particles 202 of the suspension 102 to aggregate in flocs. Flocculants may comprise inorganic salts or water-soluble organic polymers.

In an embodiment, the information processing unit 112 may control the chemical actuator CHEMICAL 1 ... CHEMICAL N which input the at least one retention agent. The at least one retention agent may optimize the operational efficiency of the process 102. The at least one retention agent may include a cationic or anionic acrylamide copolymer. A retention agent may also be a flocculant.

In an embodiment, the information processing unit 112 may control the chemical actuator CHEMICAL 1 ... CHEMICAL N which input the at least one deinking agent for optimizing deinking in the process 102.

In an embodiment, the information processing unit 112 may control at least one mechanical actuator 124 which inputs operational power for mechanical processing of the suspension 102. In an embodiment, the mechanical processing may be refining. The mechanical actuator may have an electric motor for which less, equal or more electrical power may be supplied on the basis of the manipulated variable from the information processing unit 112, for example.

In an embodiment, the information processing unit 112 may control at least one water removal actuator 126 which is associated with removal of water from the process 110. Water may be removed through a wire, by a press or in a drying section (see Figure 11).

Figure 7 illustrates an example of a dependence of fiber widths in suspensions having various process control chemicals C1 to C11. The widths are in the vertical axis in micrometers, and the reference R and the suspensions with the process control chemicals C1 to C11 are in the horizontal axis. The suspension 202, which is the reference R, has no process control chemical. The process control chemicals C1 to C11 has been dosed the same amount to the same volume of identical samples of suspension which is similar to the suspension of the reference R. It can be seen that different process control chemicals C1 to C11 cause different increase in widths of the fibers. The width may change because smaller solid particles attach to the fibers. In general, the width of solid particles may change because smaller solid particles attach to larger solid particles because of the effect of the process control chemicals C1 to C11. Thus, to control the process 110, the controller may select a suitable process control chemical C1 to C11 on the basis of the state of the attachment of the solid particles 202. Typically the controller may also have the reference size of the solid particles available. The state of the attachment of the solid particles may be measured as the width of the solid particles 202. Any of the fiber widths caused by various process control chemicals C1 to C11 may be used as a target or a set-point. Alternatively, any of the fiber widths caused by various process control chemicals C1 to C11 may be used as the fiber reference.

Figure 8 illustrates an example of formulation of fiber flocks with respect to the process control chemicals C1 to C11. The number of fiber flocks is in the vertical axis, and the reference R and the suspensions with the process control chemicals C1 to C11 are in the horizontal axis. The continuous line 800 illustrates a size category of large fiber flocks which are larger than 1.3 mm, and the dashed line 802 refers to a size category of small fiber flocks which are smaller than 1.3 mm. It can be seen that different process control chemicals C1 to C11 cause different changes in the fiber flock sizes. It can also be seen that different process control chemicals C1 to C11 cause different changes in the different fiber flock size categories. Thus, to control the process 110, the controller may select a suitable process control chemical C1 to C11 on the basis of the state of the attachment of the solid particles 202. Typically the controller may also have the target size of the solid particles which may be the set value available. The state of the attachment of the solid particles may be measured using at least one size category of the fiber flocks which are in this embodiment the solid particles 202. Any of the fiber flock sizes caused by various process control chemicals C1 to C11 may be used as a target or a set-point.

Figure 9 illustrates an example of formulation of fines and filler flocks with respect to the process control chemicals C1 to C11. The number of fines and filler flocks is in the vertical axis, and the reference R and the suspensions with the process control chemicals C1 to C11 are in the horizontal axis. It can be seen that different process control chemicals C1 to C11 cause different changes in the fines and filler flock sizes. Thus, to control the process, the controller may select a suitable process control chemical C1 to C11 on the basis of the state of the attachment of the solid particles 202 and the target size of the solid particles which may be the set value. The state of the attachment of the solid particles may be measured using at least one size category of the fines and filler flocks which are in this embodiment the solid particles 202. Any of the fines and filler flocks' sizes caused by various process control chemicals C1 to C11 may be used as a target or a set-point.

Figure 10 illustrates an example of distribution of different sized solid particles in five fractions with respect to the process control chemicals C1 to C11. The vertical axis denotes a percentage (%) of particles in each fraction, and the reference R and the suspensions with the process control chemicals C1 to C11 are in the horizontal axis. The fractions at each process control chemical C1 to C11 are from the left to right: fraction 1, fraction 2, fraction 3, fraction 4 and fraction 5. The fraction 1 includes flocks and long fibers. The fraction 2 includes long fibers. The fraction 3 includes fibers. The fraction 4 includes short fibers and fines. The fraction 5 includes fines and fillers. It can be seen that different process control chemicals C1 to C11 cause different changes in different fractions. Any of the distributions of different sized solid particles in the fractions caused by various process control chemicals C1 to C11 may be used as a target or a set-point.

In an embodiment, the controller may control the deviation of the relation between percentages of the particles of the different sizes from the particle ratio target by selecting at least one suitable process control chemical to modify the distribution of at least one fraction in the suspension 102. Here the different sizes refer to different fractions, for example.

Figure 11 shows an example of a structure of a paper machine. One or more stocks are fed onto a paper machine through a wire pit silo 1106, which is usually preceded by a blending chest 1102 for partial stocks and a machine chest 1104. The machine stock is dispensed for a short circulation, for instance, controlled by a basis weight control or a grade change program. The blending chest 1102 and the machine chest 1104 may also be replaced by a separate mixing reactor (not shown in Figure 11), and the dispensing of the machine stock is controlled by feeding each partial stock separately by means of valves or another flow control means 1100. Different stocks may be monitored with the image capturing device 100 and the state of each of the stock suspension may be measured with the information processing unit 112. In the wire pit silo 1106, water is mixed into the machine stock to obtain a desired consistency for the short circulation (dashed line from a former 1120 to the wire pit silo 1106). From the obtained stock it is possible to remove sand (centrifugal cleaners), air (deculator) and other coarse material (pressure filter) using cleaning devices 1108, and the stock is pumped with a pump 1110 to a headbox 1116. Prior to the headbox 1116, for improving the quality of the end product, it is possible to add to the stock, through valves 1112, 514, a filling agent TA and/or a retention agent RA, which are process control chemicals and affect the flocking.

From the headbox 1116 the suspension is fed via a slice opening 1118 to a former 1120. In the former 1120, water drains out of the web 10 and additionally solids, such as ash, fines and fibres, are led to the short circulation. In the former 1120, the stock is fed as a web 10 onto a wire, and the web 10 is preliminarily dried and pressed in a press 1122. Formation refers to non-uniform distribution of the solid particles when the stock is fed on the wire. Formation may also be defined as variation in the basis weight of the end product which, in turn, is based on the variation of solid material per area unit (i.e. "basis weight") in the web 10. Formation depends on flocculation. Formation may be adjusted, in addition to or alternatively from a direct flocculation regulation with the at least one process control chemical, by the former 1120 which may be controlled by the controller 1124. The amount of water of the web 10 on the wire may be adjusted with a slice opening 1118 of the headbox 1116 which may be controlled by the controller 1124. That is, water may be removed in advance from the web 10 with the slice opening 1118 of the headbox 1116.

The amount of solid and the moisture content are directly interdependent variables. If the moisture content is 45%, the amount of solid is 100% - 45% = 65%, for example.

In this application, the web 10 is considered a suspension until the water content in the web 10 has decreased excessively. Water may be removed from the web 10 using the press 1122 which may be controlled by the controller 1124. Generally, the web 10 is not actually suspension after the press 1122, and consequently the measurement method presented in this application may no longer be applicable after the press 1122. However, the control of the end product may be performed also after the press 1122. For example, water may be removed from the web 10 at a drying section (not shown in Figures) which may be controlled by the controller 1124. The drying section may be after the press 1122.The paper machine may comprise at least one measuring part 1134 which, in turn, may comprise the image capturing device 100. The measuring part 1134 may also comprise the dilution sub-process 500.

Figure 11 also shows a control arrangement of a paper machine. Factors affecting the quality and grade change include, inter alia, the amount and mutual proportion of partial stocks, the amount of filler, the amount of retention agent, machine speed, the amount of white water and drying capacity. The controller 1124, which may include or be operatively coupled with the information processing unit 112, may control the dispensing of partial stocks by means of valves 1100, the dispensing of each filler TA by means of the valve 1112, the dispensing of the retention agent RA by means of the valve 1114, adjust the size of the slice opening 1118, control the machine speed, control the amount of white water and the drying process. The controller 1124 may utilize the at least one measuring part 1134 so as to measure the suspension 102 for making the web 10 on the wire. The controller 1124 may receive data on the stock, process control chemicals and/or the web also from elsewhere.

The process controller 1124 may comprise, for instance, a PID (Proportional-Integral-Derivative), a fuzzy logic controller, an MPC (Model Predictive Control) or a GPC (General Predictive Control) controller.

The advanced process controller 1124 may form sets of control actions for a plurality of actuators including the solid particle actuators 120, chemical actuators 122, mechanical actuators 124 and water removal actuators 126, 1120, 1122 in order to regulate various properties of the process 110 and to have the end product with desired quality. The advanced process controller 1124 may form the control actions repeatedly in an iterative manner. The control actions are meant to give new operating settings to the plurality of actuators. The new operating settings may be the same as the previous ones or the new operating settings may be different from the previous ones. New control actions may carry information about a deviation with respect the present settings.

In addition to this, it is clear that the operation of a paper machine is known per se to a person skilled in the art, and therefore, it need not be presented in greater detail in this context.

The apparatus may help maintain paper quality, allow faster grade changes and result in optimization of drainage and retention in the paper manufacturing process. In general, the apparatus may increase production in the process 110.

Figure 12 is a flow chart of the measurement method. In step 1200, at least one measurement image 200 of suspension 102 is captured by an image capturing device 100. In step 1202, the at least one measurement image 200 is received 1202, and a state of attachment of the solid particles 202 of the suspension 102 together is determined on the basis of pattern recognition applied to the at least one measurement image 200 by an image processing sub-unit 104. In step 1204, suspension data associated with at least one of the following: at least one process control chemical, fiber content, fines content, stock type content, relation between particles of different sizes, and water content, is determined by a data processing sub-unit 106 on the basis of the state of the attachment of the particles 202 of the suspension 102.

The method shown in Figure 12 may be implemented as a logic circuit solution or computer program. The computer program may be placed on a computer program distribution means for the distribution thereof. The computer program distribution means is readable by a data processing device, and it encodes the computer program commands, carries out the measurements and optionally controls the processes on the basis of the measurements.

The computer program may be distributed using a distribution medium which may be any medium readable by the controller. The medium may be a program storage medium, a memory, a software distribution package, or a compressed software package. In some cases, the distribution may be performed using at least one of the following: a near field communication signal, a short distance signal, and a telecommunications signal.

It will be obvious to a person skilled in the art that, as technology advances, the inventive concept can be implemented in various ways. The invention and its embodiments are not limited to the example embodiments described above but may vary within the scope of the claims.

Claims

1. An apparatus for measuring suspension, wherein the apparatus comprises

an information processing unit;

an image capturing device configured to capture at least one measurement image from the suspension of a manufacturing process or from a sample of the suspension of a manufacturing process, a sampler of the sample being controlled by the information processing unit, the at least one measurement image presenting at least one solid particle

a dilution sub-process which comprises a fractionator configured to provide at least one fraction which includes a desired size range of the particles of the suspension for the image capture by the image capturing device; and

the information processing unit configured to receive the at least one measurement image and determine a state of attachment of the solid particles of the suspension to each other on the basis of pattern recognition applied to the at least one measurement image; and

the information processing unit is configured to determine, on the basis of the state of the attachment of the solid particles of the suspension, suspension data associated with at least one of the following: at least one process control chemical, at least one fiber property, at least one fines property, a relation between solid particles of different sizes, formation, and water content.

2. The apparatus of claim 1, wherein the information processing unit is configured to determine, on the basis of the state of the attachment of the solid particles of the suspension, the data associated with at least one of the following: deviation of an amount of at least one process control chemical from a chemical reference or from a chemical target, deviation of the fiber property from a fiber reference or from a fiber target, deviation of the fines property from a fines reference or from a fines target, deviation of the relation between particles of different sizes from a particle reference or from a particle target, deviation of

flocking from a flocking reference or from a flocking target, and deviation of the water content from a water reference or from a water target.

3. The apparatus of claim 1 or 2, wherein the information processing unit is configured to determine data associated with a zeta potential value of the suspension directly or indirectly on the basis of the suspension data.

4. The apparatus of any one of claims 1 to 3, wherein the information processing unit comprises

one or more processors;

one or more memories including computer program code; and

the one or more memories and the computer program code configured to, with the one or more processors, cause the apparatus at least to:

perform the pattern recognition to the measurement image on the basis of at least one pattern recognition algorithm;

determine the state of the attachment of the solid particles of the suspension to each other on the basis of the pattern recognition; and

determine the suspension data.

5. The apparatus of claim 1, wherein the dilution sub-process is configured to take a sample from the process, dilute the sample to a desired consistency, and provide, for the image capture by the image capturing device, the diluted sample.

6. The apparatus of claim 1, wherein the information processing unit is configured to determine, on the basis of the states of the attachment of the particles in a plurality of fractions of the suspension, the suspension data.

7. An apparatus for controlling a process of suspension, wherein the apparatus comprises the apparatus of claim 1 for measuring a process associated with water suspension including the solid particles; and

the information processing unit is configured to control, on the basis of said suspension data, whether to keep unchanged or change property related to at least one of the following in the process: at least one process control chemical, fibers, fines, stock type, solid particles of one size with respect to solid particles of at least one other size, formation, and water.

8. The apparatus of claim 7, wherein the information processing unit is configured to control the input of the at least one process control chemical to the process.

9. The apparatus of claim 8, wherein the information processing unit is configured to control the input of at least one flocculant for optimizing flocking of the solid particles in the process.

10. The apparatus of claim 8, wherein the information processing unit is configured to control the input of at least one retention agent for optimizing the operational efficiency of the process.

11. The apparatus of claim 7, wherein the information processing unit is configured to control the input of at least two types of stock to the process.

12. The apparatus of claim 7, wherein the information processing unit is configured to control the input of operational power for mechanical processing of the suspension.

13. The apparatus of claim 7, wherein the information processing unit is configured to control removal of water from the process.

14. The apparatus of claim 7, wherein the information processing unit comprises

one or more processors;

one or more memories including computer program code; and

the one or more memories and the computer program code configured to, with the one or more processors, cause the information processing unit at least to:

perform the pattern recognition to the image;

determine the state of the attachment of the particles of the suspension together on the basis of at least one algorithm of the pattern recognition, and

control at least one of the input to and the output from the process on the basis of said suspension data.

15. A method for a process associated with suspension including solid particles, the method comprising

capturing by an image capturing device at least one measurement image from the suspension of a manufacturing process or from a sample of the suspension of a manufacturing process, a sampler of the sample being controlled by an information processing sub-unit , the method comprising

providing, by a fractionator, at least one diluted fraction which includes a desired size range of the particles of the suspension for the image capture by the image capturing device;

receiving the at least one measurement image and determining, by an image processing sub-unit, a state of attachment of the solid particles of the suspension together on the basis of pattern recognition applied to the at least one measurement image; and

determining, by a data processing sub-unit on the basis of the state of the attachment of the particles of the suspension, suspension data associated with at least one of the following: at least one process control chemical, fiber content, fines content, stock type content, relation between particles of different sizes, formation , and water content.

16. The method of claim 15, the method further comprising determining, on the basis of the state of the attachment of the particles of the suspension, the suspension data associated with at least one of the following: deviation of an amount of at least one process control chemical from a chemical reference or from a chemical target, deviation of a fiber property from a fiber reference or from a fiber target, deviation of a fines property from a fines reference or from a fines target, deviation of the relation between particles of different sizes

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from a particle reference or from a solid particle target, and deviation of the water content from a water reference or from a water target.

17. The method of claim 15, the method further comprising determining a zeta potential value of the suspension on the basis of the suspension data.

18. The method of claim 15, the method further comprising controlling, by a controlling unit, at least one of an input to and an output from the process on the basis of said suspension data.

19. The method of claim 15, the method further comprising taking a sample from the process, diluting the sample and providing the diluted sample for the image capture.

20. The method of claim 19, the method further comprising forming at least two fractions from the suspension, and determining, on the basis of the states of the attachment of the particles in a plurality of different fractions of the suspension, the suspension data.

21. The method of claim 15, the method further comprising controlling, by the information processing unit, on the basis of said suspension data, whether to keep unchanged, or change or change property related to at least one of the following in the process: at least one process control chemical, fibers, fines, stock type, solid particles of one size with respect to solid particles of at least one other size, formation, and water.

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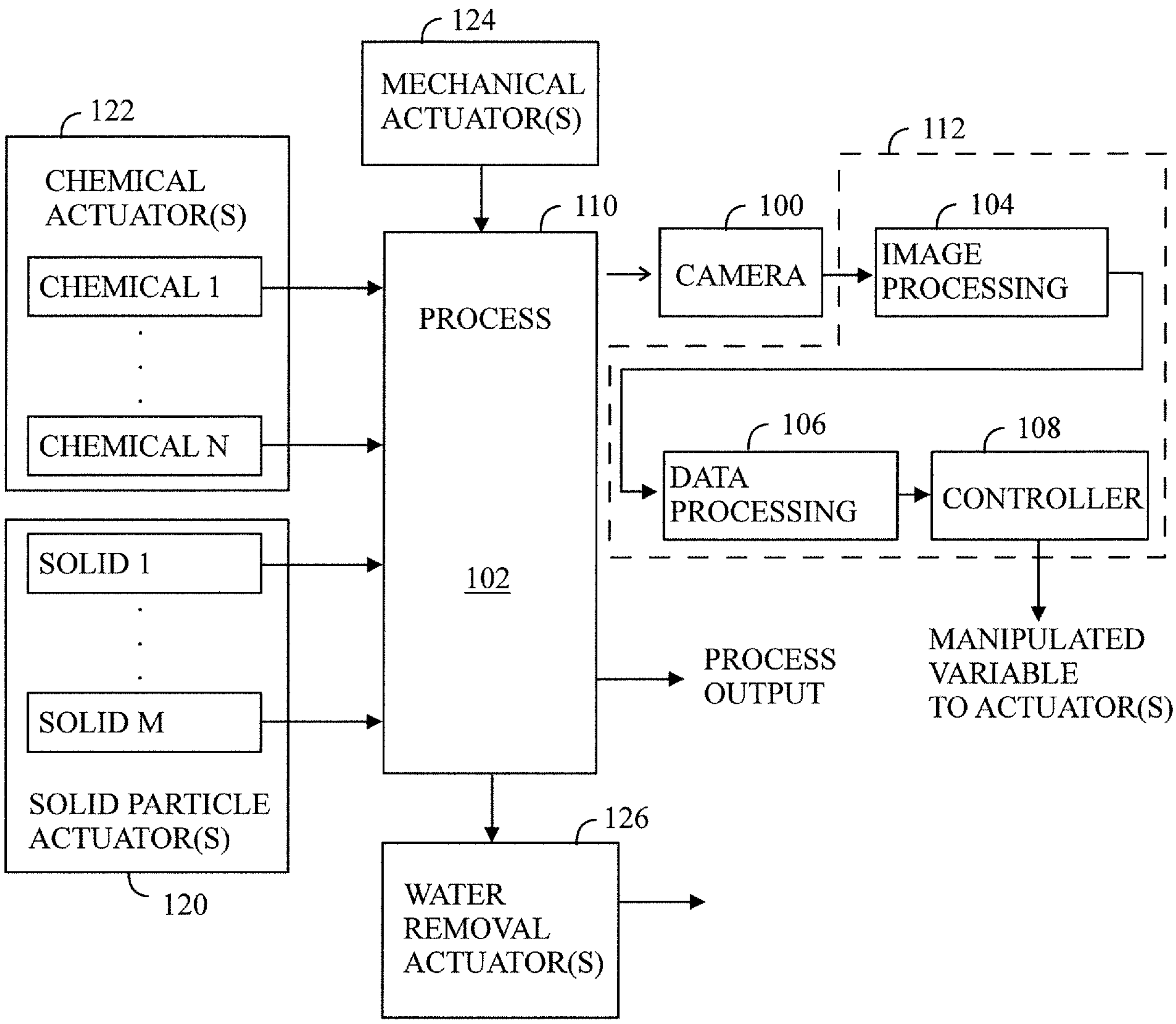
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122
CHEMICAL ACTUATOR(S)
CHEMICAL 1
CHEMICAL N
SOLID 1
SOLID M
SOLID PARTICLE ACTUATOR(S)
120
110
PROCESS
102
112
100
CAMERA
104
IMAGE PROCESSING
106
DATA PROCESSING
108
CONTROLLER
MANIPULATED VARIABLE TO ACTUATOR(S)
PROCESS OUTPUT
126
WATER REMOVAL ACTUATOR(S)

FIG. 1

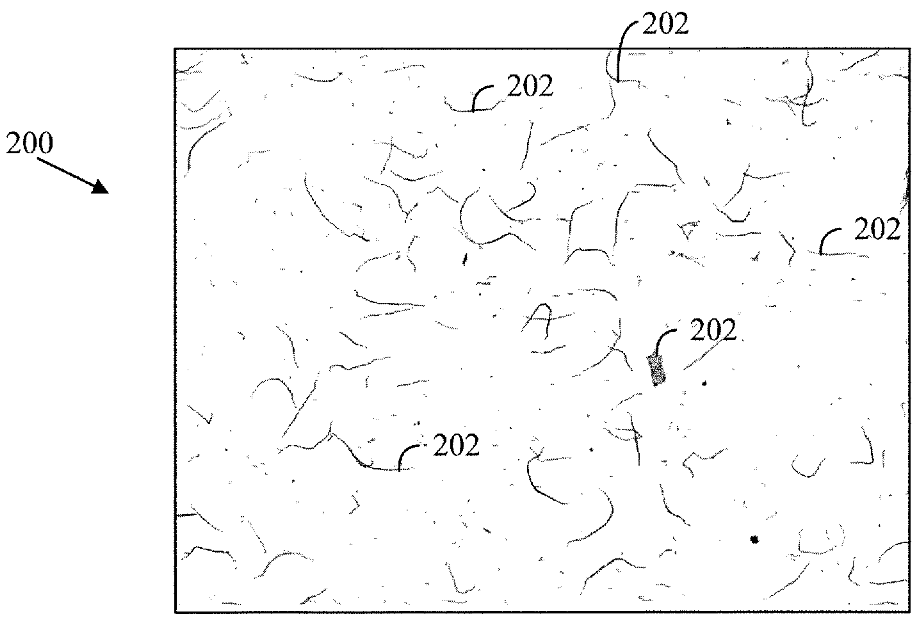

200
202
202
202
202
202

FIG. 2A

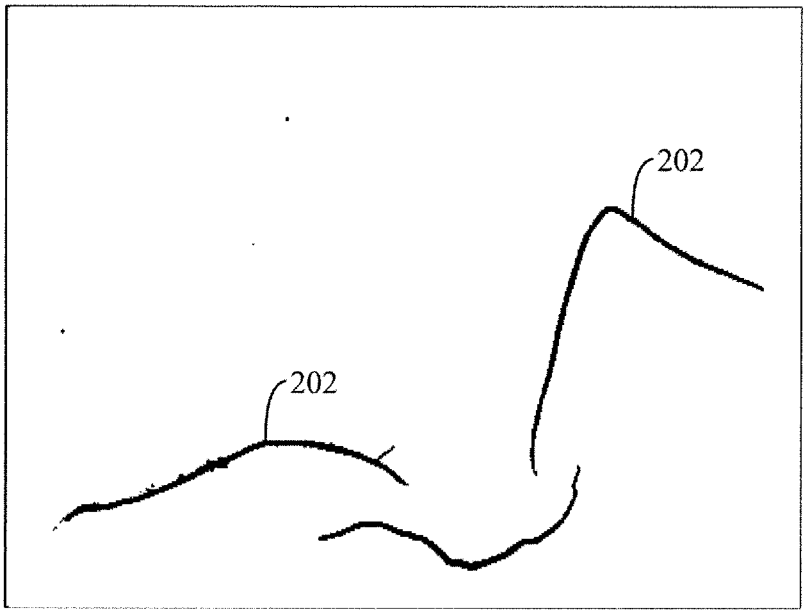


FIG. 2B

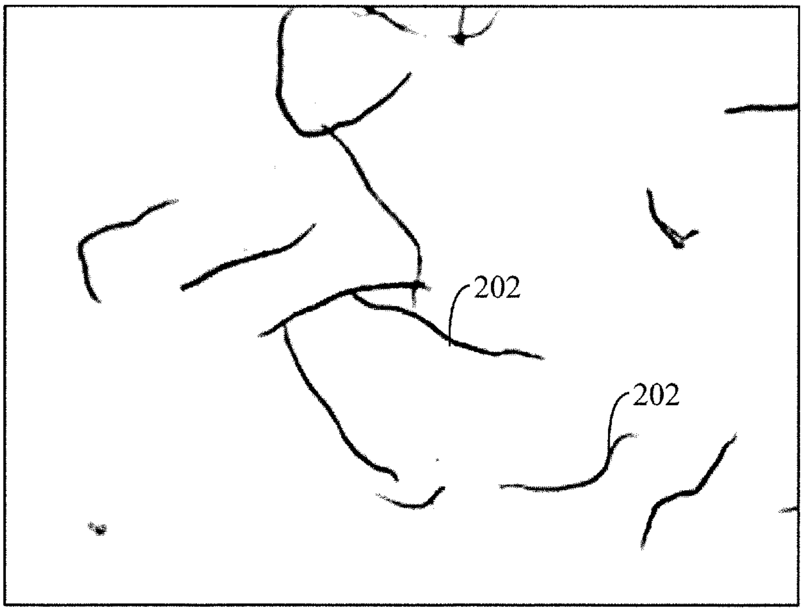


FIG. 2C

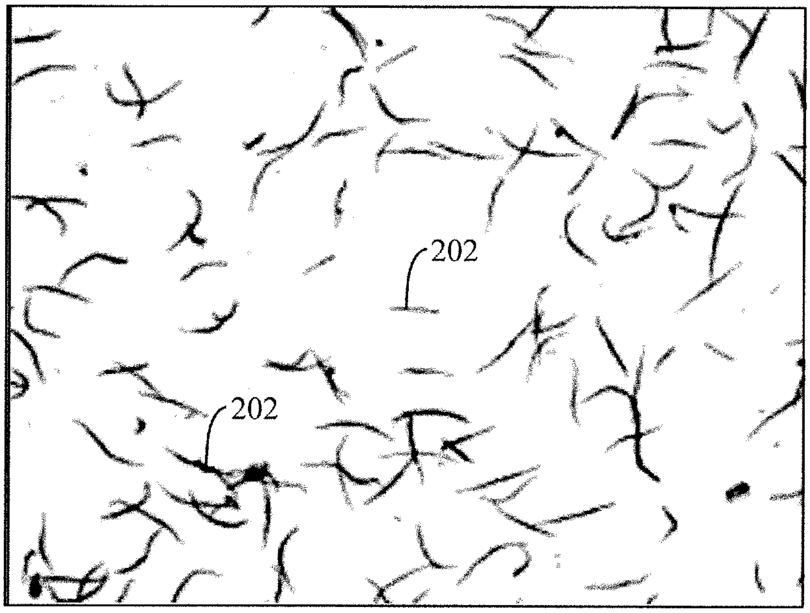


FIG. 2D

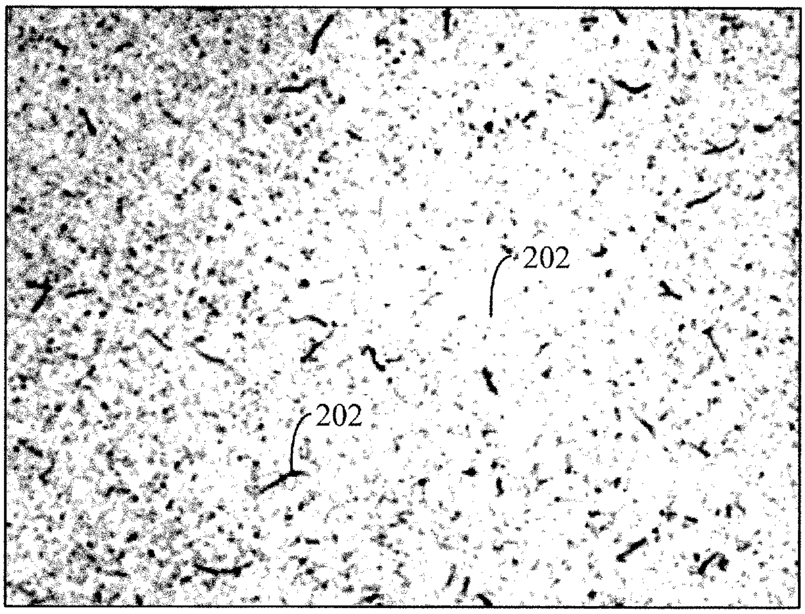


FIG. 2E

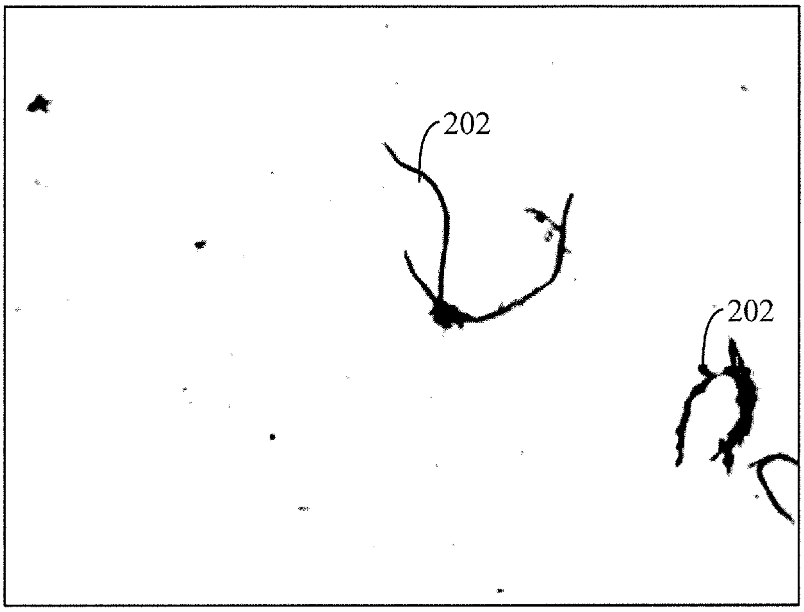


FIG. 3A

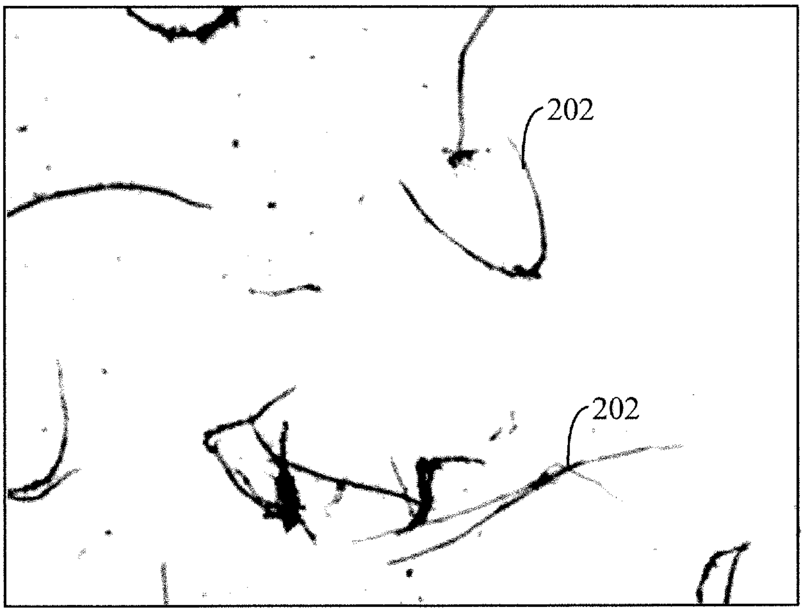


FIG. 3B

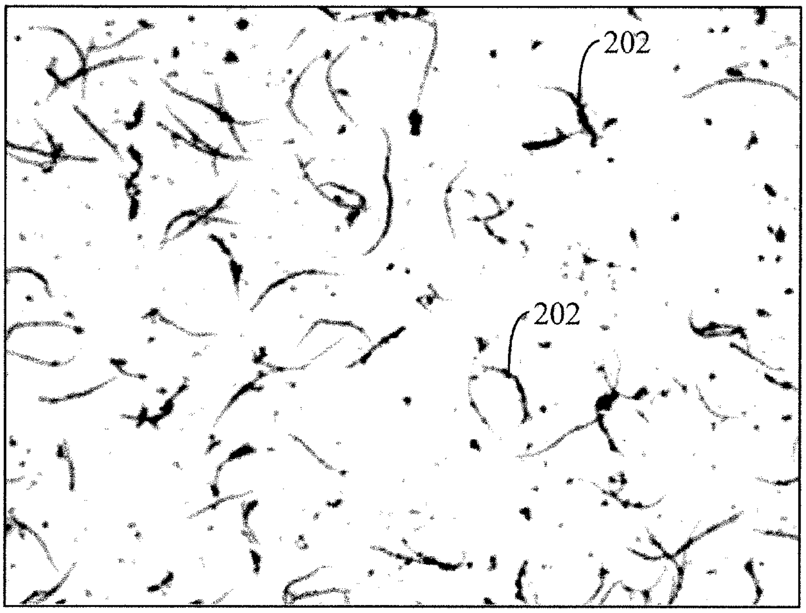


FIG. 3C

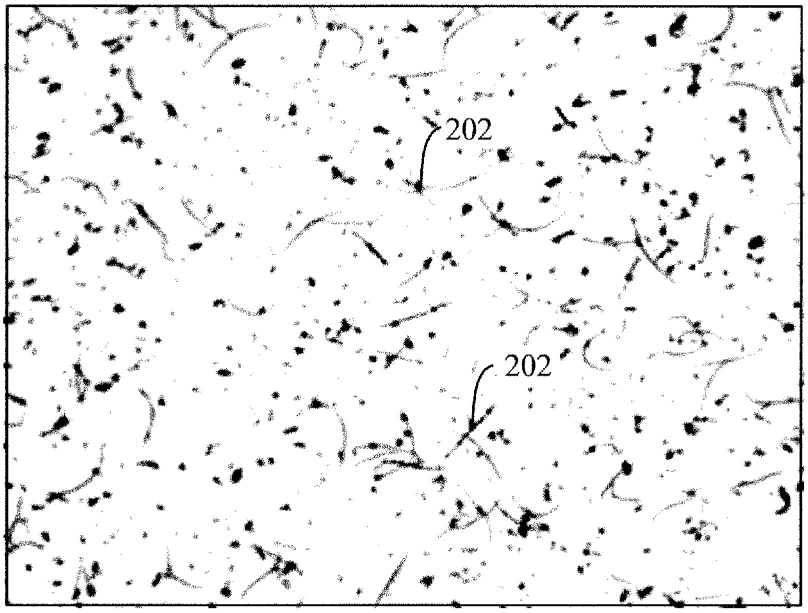


FIG. 3D

6/10

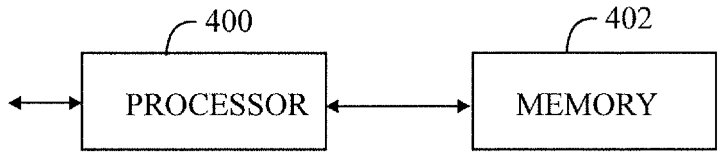


FIG. 4

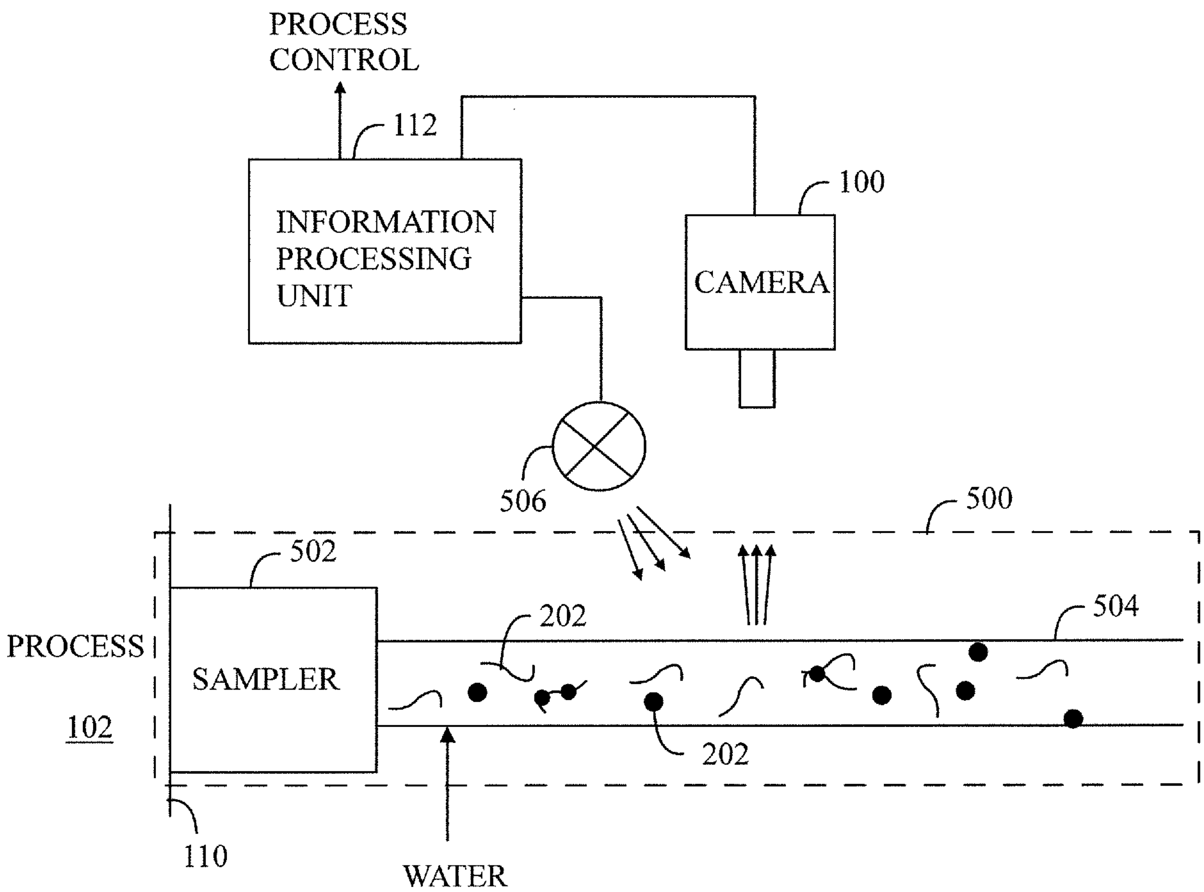


FIG. 5

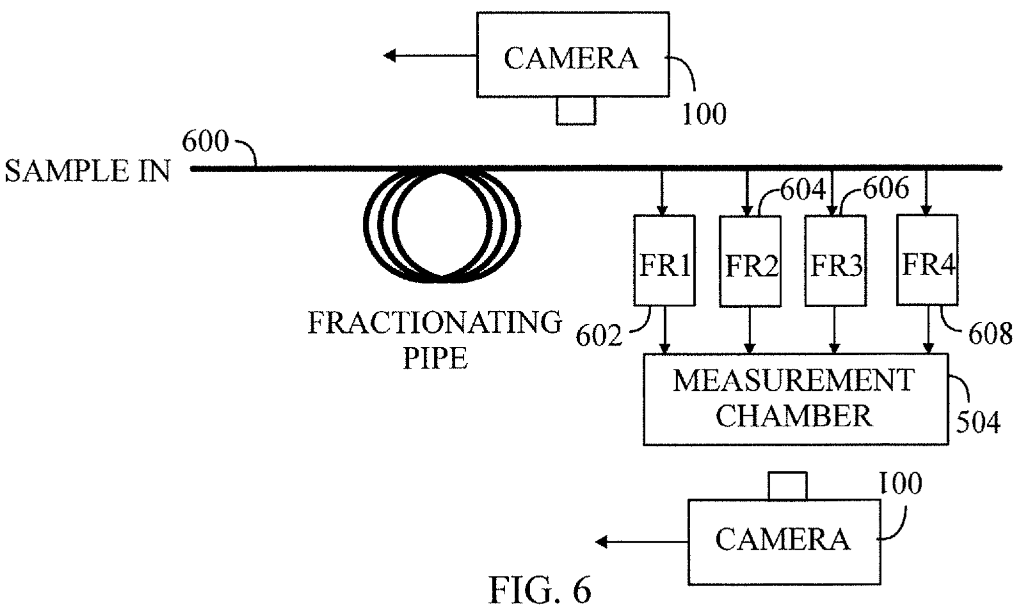


FIG. 6

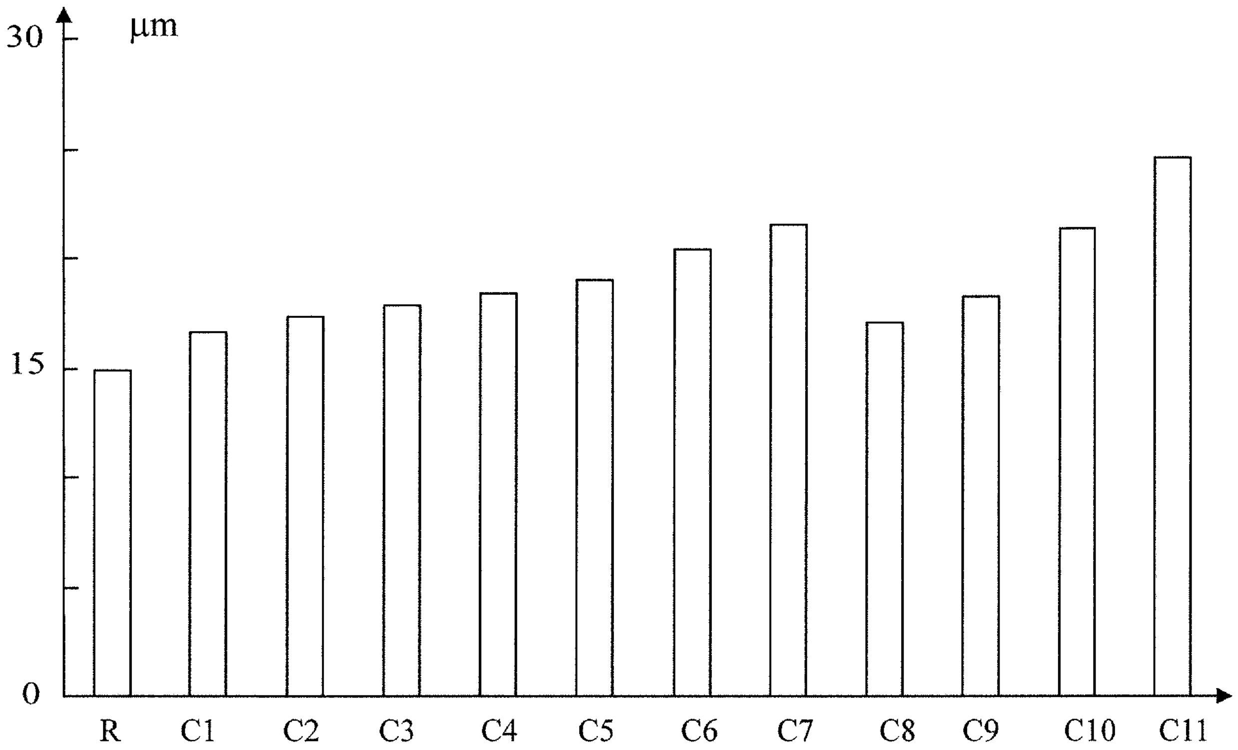
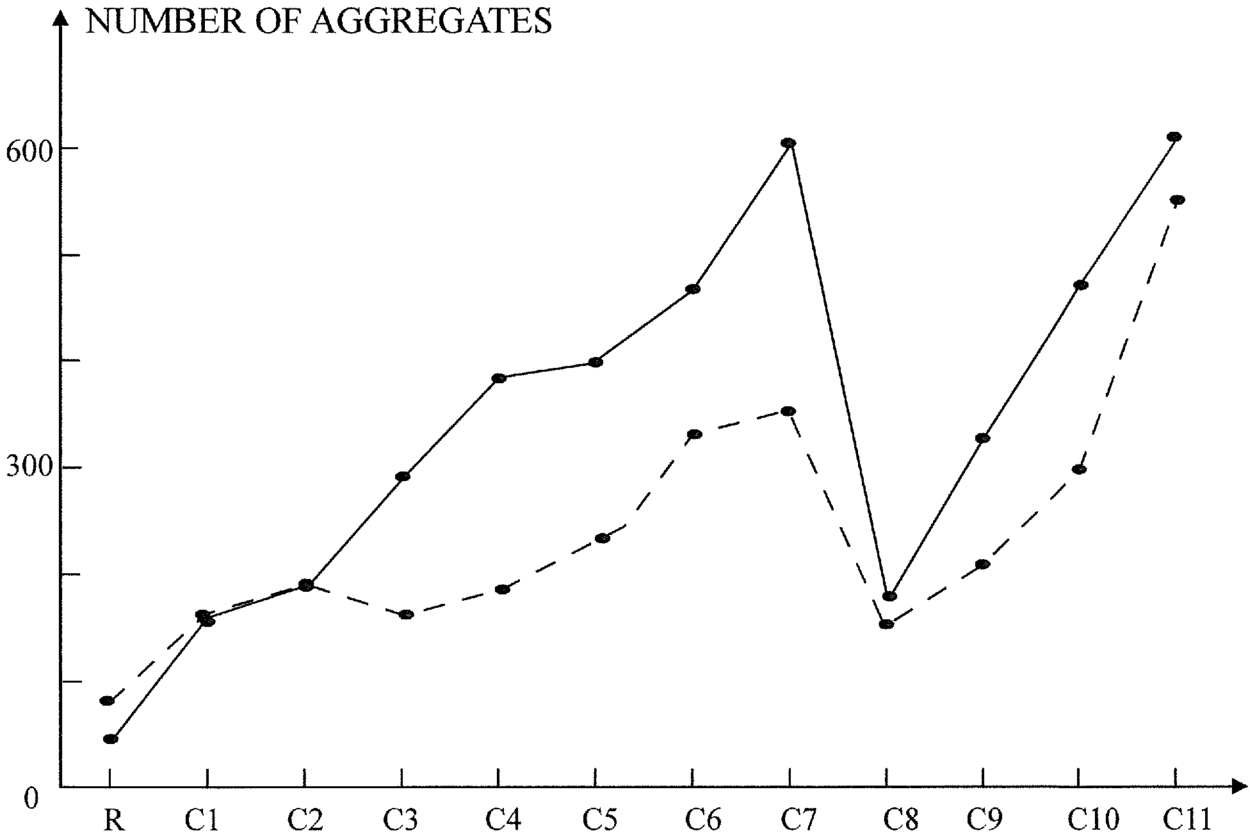

30
µm
15
0
R
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11

FIG. 7


NUMBER OF AGGREGATES
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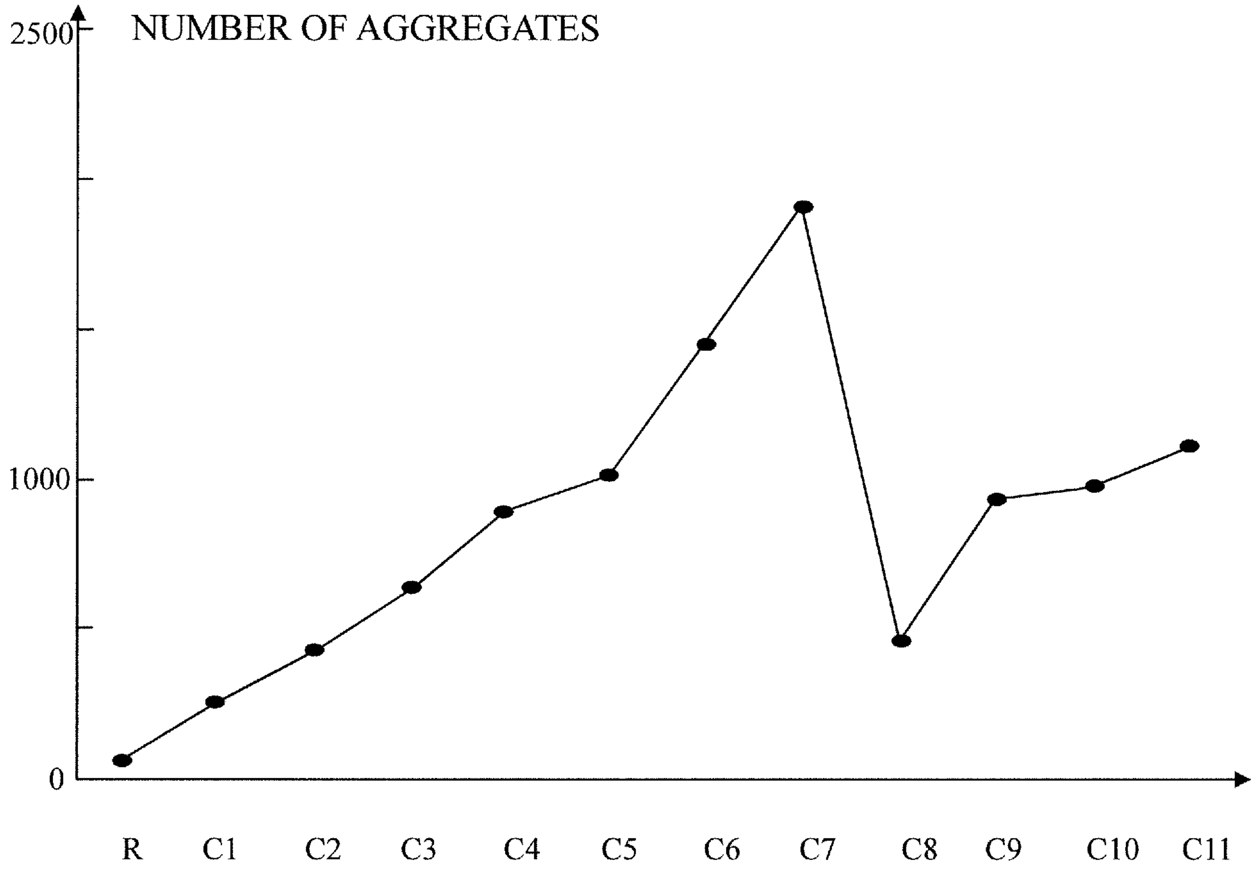
300
0
R
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11

FIG. 8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NUMBER OF AGGREGATES
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R
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11

FIG. 9

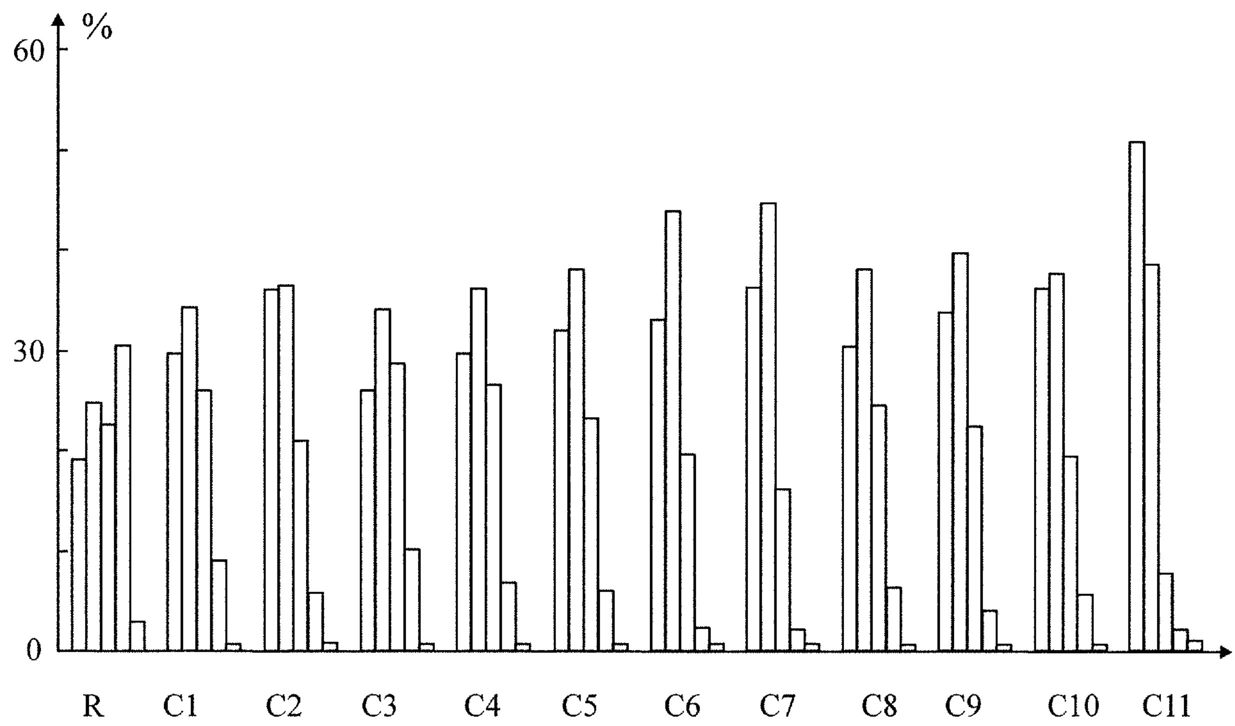

%
60
30
0
R
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11

FIG. 10

9/10

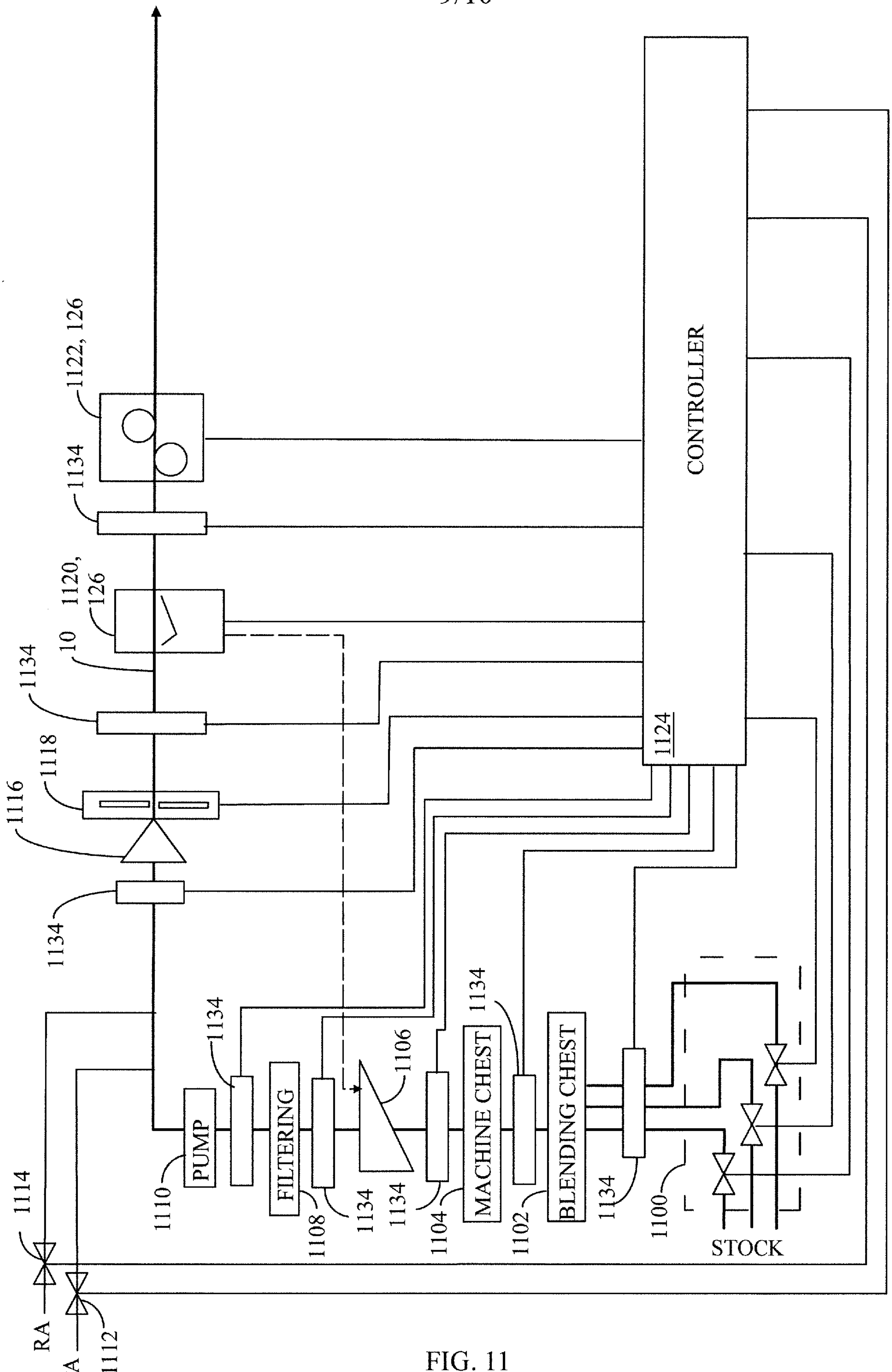

1122, 126
1134
1120, 126
10
1134
1118
1116
1134
CONTROLLER
1124
1114
1110
PUMP
1134
FILTERING
1108
1134
1106
1134
1104
MACHINE CHEST
1134
1102
BLENDING CHEST
1134
1100
STOCK
RA
TA
1112

FIG. 11

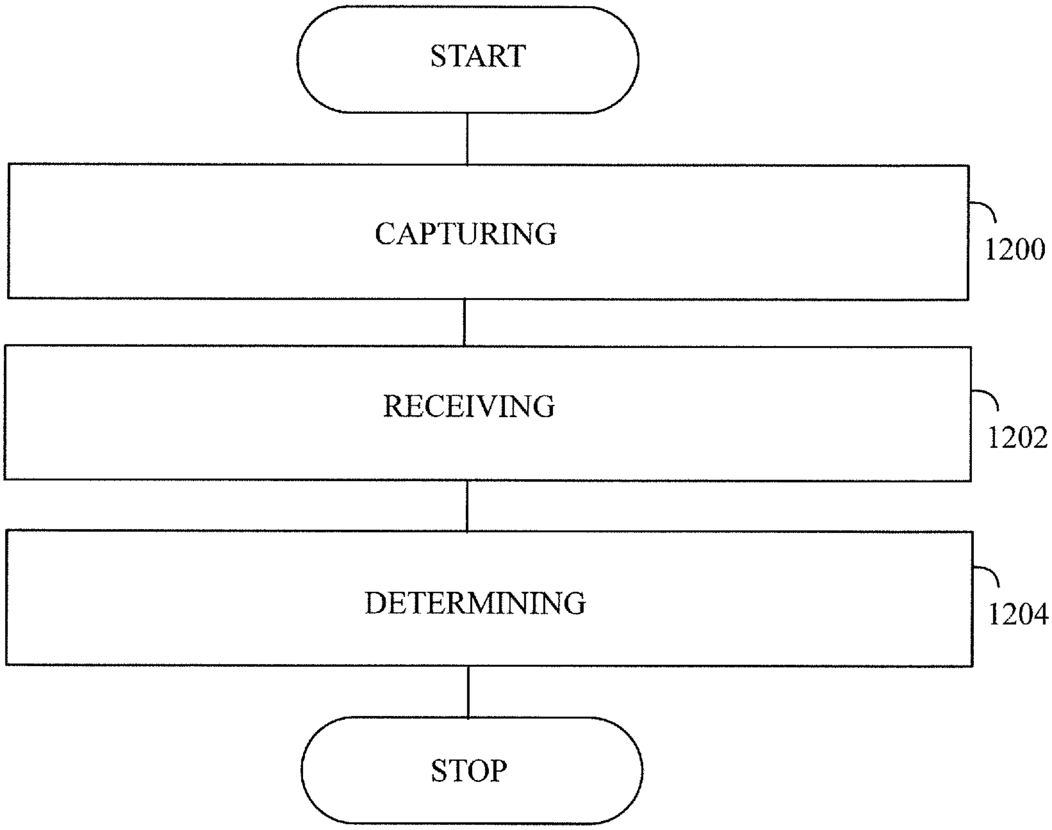
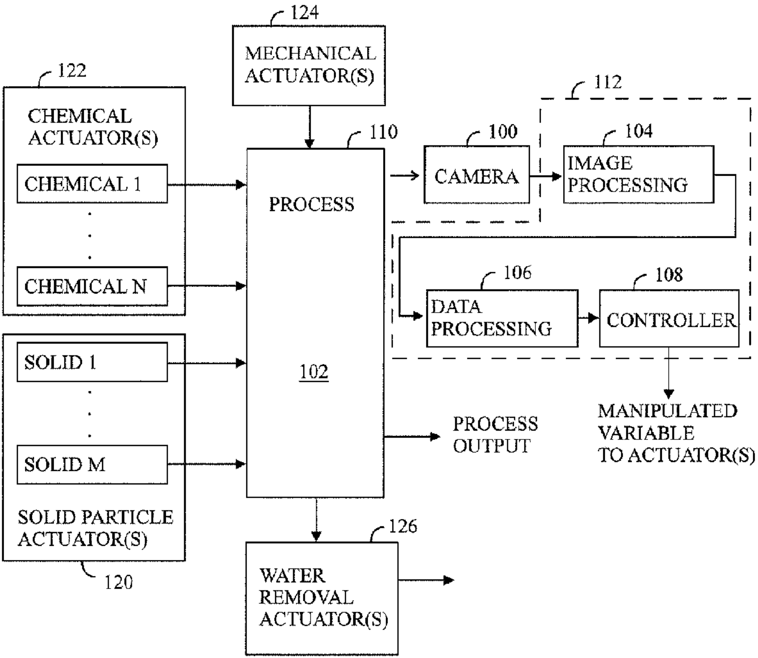

START
CAPTURING
1200
RECEIVING
1202
DETERMINING
1204
STOP

FIG. 12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CHEMICAL ACTUATOR(S)
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PROCESS
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IMAGE PROCESSING
106
DATA PROCESSING
108
CONTROLLER
SOLID 1
SOLID M
SOLID PARTICLE ACTUATOR(S)
120
PROCESS OUTPUT
MANIPULATED VARIABLE TO ACTUATOR(S)
126
WATER REMOVAL ACTUATOR(S)