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(54) Method for inspecting an elongated element made of fibrous material

(57) A method for inspecting an elongated element for smoking articles comprises the steps of: obtaining at least a first profile (2) of a first measurable physical quantity, for example density, and a second profile (4) of a second measurable physical quantity, for example humidity, by means of at least one sensor interacting with the elongated element along the same elongated element; processing at least one of the first profile (2) and the second profile (4) to determine the presence of at least one capsule made of non-fibrous material, for example an aromatising additive inserted inside the elongated element; if the capsule is present, evaluating the intactness of the capsule, comparing the first (2) and the second profile (4) respectively with a first (16, 17) and second threshold reference (21, 22). The method further comprises the steps of moving the first profile (2) and the second profile (4) to an ideal reference position of the capsule along the elongated element; establishing, during the operational functioning, the first threshold reference (16, 17) by statistical processing of the first profile (2); establishing the second threshold reference (21, 22) by statistical processing of the second profile (4), the first and the second statistical processing being performed respectively on moved profiles of a preceding inspection cycle, defined by a predetermined number of inspected elements.

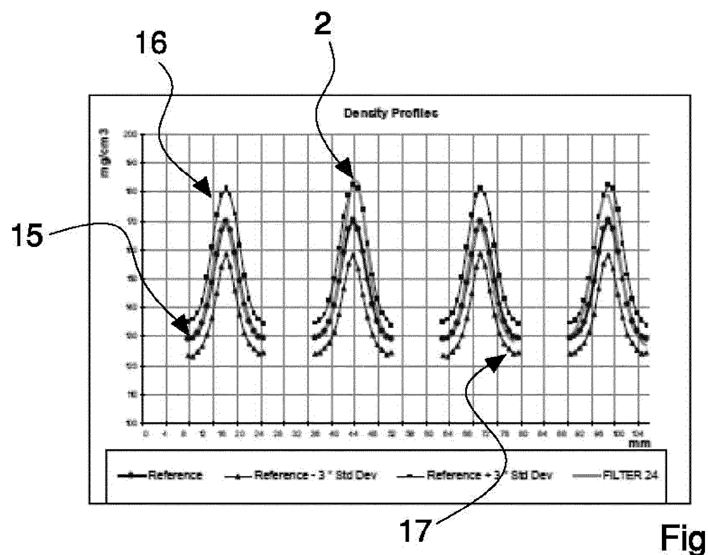

Fig. 9

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Description

[0001] The invention relates to a method for inspecting an elongated element, in particular a rod-shaped elongated element made of fibrous material for determining the quality of a capsule of non-fibrous material inserted into the elongated element.

[0002] In particular, by the term "fibrous raw material" fibres of filtering material are intended (for example cellulose acetate) intended for forming a continuous rod of filter in a machine, either single or double line, for producing smoking articles such as cigarette filters, and alternatively the tobacco fibres intended for forming a rod of tobacco in a machine, either single or double line, for producing smoking articles such as cigarettes. The rod-shaped elongated element, can therefore be a continuous filter rod, or a portion of rod-shaped filter, or a portion of filter in a smoking article, or a continuous rod of tobacco, or a portion of a rod of tobacco in a cigarette.

[0003] A cigarette is one of the products of the tobacco industry, comprising a part of tobacco wound by paper joined to a portion of filter, which is able to retain the substances generated by the combustion of the tobacco.

[0004] For a long time already, it has been known to propose the production of portions of filter incorporating additive substances into the filtering material, which are in particular immersed therein. Such aromatising additive substances, which are supplied, for example, in liquid form as in the case of menthol, are contained in capsules. Such capsules can be of spherical or elongated shape and can contain one or more aromatising additive substances. In this latter case, each of the different aromatising substances is received in a separate compartment of the capsule.

[0005] The capsules can be breakable by mechanical action, and i.e. crushing, by a user immediately before consumption of the smoking article. The user is thus able to decide whether to consume a cigarette or not, the filter of which is aromatised.

[0006] Proposing making portions of rods of tobacco is also known in which capsules containing aromatising additive substances are mixed with tobacco fibres. Also in this case the aromatising additive substances are provided in liquid form and are contained in microcapsules but the microcapsules comprise in this case a heat-sensitive shell. During consumption of the smoking article, the action of the heat generated by the combustion of the tobacco fibres weakens the shell of the capsule that, upon breaking, releases the aromatising substance that is suitable for soaking the tobacco fibres. The user can thus take advantage of an aromatised smoking article in which the aroma is dispersed only at the moment of consumption.

[0007] In order to improve even further the quality of an elongated element made of fibrous material containing internally a capsule made of non-fibrous material, over time increasingly refined inspection methods for the elongated element have therefore been proposed. In particular, inspection methods have been proposed for checking that the position of the capsule or of the capsules, that is or are inserted into the fibrous raw material conforms to the required quality standards. The inspection can occur on-line, i.e. during production by control of all the elongated elements produced, or off-line, at the end of the production process only on certain selected elongated elements, if more precise but also slow measuring instruments than those used on-line are needed.

[0008] We observe first of all that the capsules containing aromatising substances have to be inserted inside each elongated element at reference positions established a priori, both longitudinally and radially with respect to a longitudinal axis of the element. If ideal reference positions established *a priori* for each capsule are considered, an acceptability interval is supplied that is defined between a minimum acceptability position and a maximum acceptability position, inside which a capsule is considered to be present and of acceptable quality. If the capsule is present but outside the acceptability interval, the elongated element is to be rejected in because it does not conform to quality requisites. The presence and correct positioning of each capsule are thus controlled by sensors that are able to detect a characteristic property of the elongated element with which the sensor interacts, when the capsule enters the measuring field of the sensor, the characteristic property being detected as a variation of the output signal of the sensor. Such variations are obtained by "scanning" in several point the elongated element and typically equidistant acquisitions are made over the entire length of an elongated element, for example every mm. This also applies in the case of a continuous rod or of portions of filter rod, or in the case of a continuous rod of tobacco or of portions of tobacco rod, or in the case of a multiportion element, in which several elongated elements are joined together. In fact, it is always possible to define the start and finish of each elongated element, even if joined to others, during production.

[0009] Several different types of sensors are indicated for identifying the presence of a capsule in an elongated element made of fibrous material, such as, for example, an optical capacitive sensor, or laser, also used together in combination. For this purpose, also microwave resonators have been successfully proposed that are usable as density and humidity sensors, which have already been used for many years during production for measuring the weight of the continuous rod of tobacco.

[0010] The profile obtained by reconstructing a density of an elongated element such as a filter rod from equidistant samples acquired from a microwave resonator, shows that at the position of each capsule present in the filter rod, a maximum peak of detected density is present. It follows that it is possible to identify the presence/absence or percentage of movement with respect to the ideal position of each capsule by merely comparing the maximum density position with the corresponding acceptability interval.

[0011] Nevertheless, the presence/movement of the capsule with respect to the ideal position is not the only parameter that determines the quality of the smoking article, inasmuch as the presence of a non-intact capsule in the fibrous raw material compromises the quality of the smoking article much more.

[0012] If in fact a capsule that is breakable by crushing releases the aromatising substance early with respect to the moment of consumption, by breaking of the capsule during or after the process of production of the filtering material incorporating the capsule, the user may no longer be able to choose whether to consume or not an aromatised smoking article, inasmuch as the filtering material presents itself to the user already aromatised at the moment of consumption. Similarly, if a heat-sensitive capsule mixed with the tobacco fibres breaks before or after the production process of the smoking article, the user will have at the moment of consumption of a smoking article the tobacco of which is devoid of the required aromatic qualities. As the aromatising substances are in fact very volatile, the smoking article will present itself to the user already aromatised, but only weakly.

[0013] In order to detect the intactness of a capsule inserted into an elongated element, it has been requested to detect the humidity thereof, in addition to the density thereof, and to check the humidity variations compared with a reference. If in fact a capsule releases the liquid contained therein into the fibrous raw material, the liquid spreads in the fibrous raw material, determining a variation in humidity in a volume of fibrous raw material surrounding the capsule and also consequently a variation in density.

[0014] The obtained profile reconstructing a humidity curve of an elongated element such as a filter rod shows that at the position of each capsule a peak of maximum of the detected humidity is present, if the capsules are intact, which increases if a non-intact capsule is present.

[0015] Also the density profile is modified in the presence of a broken capsule, as is clearly shown by the experimental tests shown in Figures 1 and in Figures 2, that respectively show a density profile and a humidity profile of a first and a second elongated element, and i.e. a filter rod, containing 4 capsules.

[0016] With 1 the reference density profile is indicated of a first elongated element in which the capsules are intact, with 2 the density profile is indicated that is detected in the presence of a second elongated element in which capsules two and four are broken.

[0017] With 3 the humidity profile of the first elongated element is shown with intact capsules, with 4 the detected humidity profile of the second elongated element is indicated, with broken capsules two and four.

[0018] It follows that it is possible to identify the intactness of each capsule, by comparing the maximum density or humidity peak at the position in which each capsule is present, with respect to a corresponding reference profile, for example defined as a threshold profile or as a predefined width threshold band, within which the detected profile has to be comprised.

[0019] Experimentally, it has nevertheless been noted that a not insignificant variability exists linked to the weight and to the dimension of the capsules and a not insignificant variability in the detectable features of the fibrous raw material. For example, depending on the production batch, the filtering material can contain variable quantities of acetate or triacetin.

[0020] Owing to this variability, the density profiles of intact capsules inside filters can also be rather different from one another and all this implies that determining the threshold profile or the width of the tolerance band is complex, inasmuch as a threshold profile defined for one production batch could be too strict (and thus impose the rejection of good quality elongated elements) or too loose (and thus consider elongated elements to be rejected to be of good quality) even for a similar production batch.

[0021] In order to overcome the problems of inspecting correctly filters despite the variability of the capsules and/or of the fibrous raw material, from WO 2011/083406 is known setting up a plurality of different types of optical, laser, capacitive, inductive or microwave sensors, that interact on line or off-line with a continuous rod or portions of filter and is able to detect components inside the filtering material. The configuring parameters of this plurality of sensors are stored in a library of the control system of the machine PLC, associated with each production batch or with each brand and such configuring parameters can be varied during operation of the system to improve the sensitivity of the system, in response to statistics on the number of filtering elements considered to be of acceptable quality or else rejected.

[0022] It should be observed that the variation of the configuring parameters, especially if complex sensors are considered that need calibrating procedures and involve several configurable parameters of the sensor and possibly need the intervention of a machine operator, it is not often always possible during production in an automatic machine but may require a machine stop and thus lower machine production in an unrequested manner. Further, although in a production batch wherein the features of the filtering material and of the capsules are known a priori, the variation of the configuring parameters of the sensors might not, however, be suitable for determining non-intact capsules in the filtering material, given the extreme variability of the features of both the filtering material and of the capsules.

[0023] A further problem of the known methods of inspection is that it is not possible to define correctly elongated elements with non-intact capsules, if the inspection is conducted after some time has elapsed after the breakage of the capsule. This occurs above all with off-line inspections, in which the elongated elements selected for inspection are also inspectable after some time has elapsed since production.

[0024] Experimentally, it has in fact been established that the result of the inspection depends on the moment at which the inspection is conducted, in the sense that if the inspection of the same elongated element is repeated time spaced the density and humidity profiles are not repeated. This is due to the highly volatile nature of the additive substances. In Figures 7 and 8 the density and humidity profiles of the elongated elements of Figures 1 and 2 recorded after 10 days are shown. In particular the breakage of capsules two and four in a filter rod was provoked and the result of the inspection within two hours of the breakage is shown in Figures 1 and 2, after 10 days in Figures 7 and 8.

[0025] It can be observed experimentally that if the elongated element is inspected after a short lapse of time from the breakage of the capsule (Figures 1 and 2), the liquid impregnating the fibrous raw material is easily detectable but this is not so if on the other hand the elongated element is inspected after a long lapse of time from the breakage of the capsule. The density profile 2 of Figures 7, at positions two and four in which the capsules are broken, shows a maximum density value peak that is much less than the value detected in Figures 1. In Figures 8, the humidity profile 4 is indeed almost superimposed on the reference profile 3.

[0026] By changing over time the properties of the elongated element, modifying the configuring parameters of the sensors used in the measurement does not enable non-intact capsules in an elongated element to be identified.

[0027] The object of the present invention is to devise a method for inspecting elongated elements made of fibrous raw material that is able to identify the presence and intactness of capsules made of non fibrous material that are inserted into the fibrous raw material, which is free of the problems disclosed above and at the same time is easy and cost-effective to develop. In particular, the object of the present invention is to provide a method for inspecting that maintains the same configuration of the measuring sensors during operation of the inspection system over time.

[0028] A further object is to provide a method for inspecting that enables non-intact capsules to be determined both immediately after breakage of the capsules and a long time after breakage and which is independent of the moment in which the inspection is conducted.

[0029] These objects and still others are all achieved by a method for inspecting an elongated element made of non-fibrous material for identifying the presence and the intactness of a capsule made of non-fibrous material inserted into the fibrous raw material, as established by claim 1 and the further claims set out below.

[0030] The invention can be better understood and implemented with reference to the attached drawings that illustrate embodiments thereof by way of non-limiting example, in which:

- Figure 1 shows density profiles of a first and of a second elongated element, such as a multi-portion filter rod containing 4 capsules, in which the first elongated element has intact capsules whereas the second elongated element has broken capsules two and four;
- Figure 2 shows respective humidity profiles, detected simultaneously on the density profiles of Figure 1, of the same first and second elongated element inspected in Figure 1;
- Figure 3 shows the density profiles obtained by the inspection method according to the invention, considering a sample of 100 filter rods;
- Figure 4 shows the humidity profiles detected simultaneously on the density profiles of Figure 3, considering the same sample of 100 filter rods;
- Figure 5 shows the density profiles of Figure 1, in association with a minimum density limit profile and with a maximum density limit profile calculated according to the method of the invention;
- Figure 6 shows the humidity profiles of Figure 2, in association with a minimum humidity limit profile and with a maximum humidity limit profile calculated according to the method of the invention;
- Figure 7 shows density profiles of the same first and second elongated element inspected in Figure 1, the inspection being conducted 10 days after the inspection of Figure 1;
- Figure 8 shows humidity profiles of the same first and second elongated element inspected in Figure 7, the inspection being conducted simultaneously as the inspection of Figure 7;
- Figure 9 shows the density profiles of Figure 1, in association with a minimum density limit profile and with a maximum density limit profile calculated according to one embodiment of the method of the invention, which provides for moving the acquired profiles;
- Figure 10 shows the humidity profiles of Figure 2, in association with a minimum humidity limit profile and with a maximum humidity limit profile calculated according to one embodiment of the method of the invention, which provides for moving the acquired profiles;
- Figure 11 shows the density profiles of Figure 7, in association with a minimum density limit profile and with a maximum density limit profile calculated without moving the profiles.
- Figure 12 shows the humidity profiles of Figure 8, in association with a minimum humidity limit profile and with a maximum humidity limit profile, calculated without moving the profiles.
- Figure 13 shows the density profiles of Figure 7, in association with a minimum density limit profile and with a maximum density limit profile calculated according to the method of the invention which provides for moving the

acquired profiles.

- Figure 14 shows the humidity profiles of Figure 8, in association with a minimum humidity limit profile and with a maximum humidity limit profile calculated according to the method of the invention which provides for moving the acquired profiles.

[0031] An inspection unit (not illustrated) of an elongated element (not illustrated) for smoking articles comprises one or more sensors that are able to interact with the elongated element to detect at least a first and a second measurable physical quantity. The elongated element is rod-shaped and is made of a first "fibrous raw material", as defined previously.

[0032] The inspection unit comprises a control device that receives the signal/s detected by the sensor or by the plurality of sensors and is able to process the signals to determine the presence of at least one capsule made of non-fibrous material inserted inside the fibrous element. The capsule is spherical or elongated and contains one or more aromatising additives, like menthol, as defined previously.

[0033] In particular, a first and a second profile are processable that are obtainable respectively by the first and second measurable physical quantity.

[0034] A microwave resonator (not illustrated) is a device which has a determined geometry, makes a resonant microwave field by means of an emitting antenna and enables the properties of the material inserted into this field to be measured by an analysis of the variations of the frequency received from a receiving antenna. By varying the frequency at which the microwave field is emitted, by measuring the power received at each emitted frequency and processing the peak value and the band width of the response curve at half the peak height, it is possible to determine a first measurable physical quantity such as the density, and i.e. the mass, and a second measurable physical quantity such as humidity of the material subjected to inspection. A microwave resonator can be considered to be a measuring unit provided with two virtual sensors that are able to measure two characteristic parameters simultaneously.

[0035] The cylindrical microwave resonators have an axial hole for receiving the material to be subjected to inspection and they are particularly used for measuring the density and humidity of a continuous filter rod or of portions thereof, in a single or double-line machine for producing cigarette filters or the density and humidity of a rod of tobacco or portions thereof, in a single or double line machine for producing tobacco rods. The continuous rod or the portion is supplied through the hole and pass through the microwave resonator for the inspection. The cylindrical resonators can also be advantageously used in off-line apparatuses comprising the inspection unit, typically designed for thorough statistical or quality analyses of samples, of portions of filters or of rods of tobacco taken from the machines during production. Resonators with different geometries, for example planar geometries, can on the other hand be advantageously positioned in machine zones, for example drums for transferring elongated elements, in which the cylindrical resonators would be too bulky.

[0036] Without loss of generality, the following discussion refers to a method for inspecting that provides density to be obtained as a first measurable physical quantity and humidity to be obtained as a second measurable physical quantity, from a microwave resonator. Nevertheless, other types of density and humidity sensors could be used, other than a microwave resonator, because more suitable for detecting variations of a specific fibrous raw material or more suitable because of small dimensions, or also sensors for detecting measurable parameters that are different from density or humidity, for example NIR-type optical sensors.

[0037] Despite the profile, for example the humidity profile, that is obtainable from a microwave resonator during inspection of an elongated element, shown in the attached figures, is shaped differently from the profile that is obtainable by an optical sensor during inspection of the elongated element (for example the presence of a capsule could be defined by a minimum in the profile and not by a maximum), it is pointed out that the method of the present invention is invariant compared with the type of sensor and the type of measured parameter considered.

[0038] The inspection unit uses the method of the present invention for inspecting an elongated element in a fibrous raw material and determining the capsule quality features of non fibrous material inserted into the elongated element. Without loss of generality, the following discussion refers to a method for inspecting that can be used on line or off-line. A programme is provided in association with the inspection unit, which comprises a code for implementing the inspection method according to the invention when this programme is run in the inspection unit itself. The programme can be for example performed by the control device of the inspection unit when stored in the inspection unit.

[0039] In use, during an operating step of the operation of the inspection unit, if the capsule is present inside the fibrous raw material, a quality feature of the capsule such as intactness is evaluated by comparing the first or the second profile with a respective first and second threshold reference, which are established dynamically. The first threshold reference is established by statistical processing of the first profile, the second threshold reference is established by statistical processing of the second profile, the first and the second statistical processing being performed on profiles obtained in the preceding inspection cycle defined by a predetermined number of previously inspected elements.

[0040] Each statistical processing is thus performed upon conclusion of each inspection cycle, is based on profiles obtained from the predetermined number of inspected elongated elements of the inspection cycle, the results of which are provided for the elongated elements inspected in the subsequent inspection cycle.

[0041] During the switch-on transient of the inspection unit in which the statistical processing of the first and of the second profile are not yet available, it is possible to provide a first and a second reference that are stored in the inspection unit, deriving from previous statistical analyses or profiles preset a priori to define the first and second reference threshold.
[0042] In order to identify the presence of the capsule, in known manner, the first or the second profile is processed to identify a maximum value, the corresponding position of which is that of the capsule in the elongated element.
[0043] The capsule is present if the position of the capsule is a research zone defined by an interval between a minimum reference position and a maximum reference position comprising an ideal reference position in such a manner that:

Formula 1

$$\text{maximum reference position capsule} = \text{ideal reference position} + \text{research threshold}$$

Formula 2

$$\text{minimum reference position capsule} = \text{ideal reference position} - \text{research threshold}$$

[0044] The search zone of the elongated element is thus that in which the first or the second profile are processed in order to define the position of the capsule.
[0045] The capsule is present and in a correct position if, on the other hand, the position of the capsule is present and is arranged inside an acceptability zone, in which, according to specifications established a priori, the capsule has to be positioned in order to be able to meet predefined quality criteria.
[0046] This acceptability zone is thus an interval of the elongated element comprised inside or coinciding with the interval that defines the research zone. If a capsule is outside the corresponding envisaged acceptability zone, the elongated element containing the capsule must be rejected, if the inspection unit is connected to the control system of the automatic machine, and runs an online control, during production of the machine.
[0047] Nevertheless, if the capsule is present in the research zone, even if it is outside the acceptability zone, this capsule can also be further analysed to evaluate the intactness thereof, as we shall see below. It is understood that if the research zone coincides with the acceptability zone, the intactness analysis is conducted only on capsules present and positioned according to predefined quality criteria.
[0048] It should be noted that the density and humidity profiles shown at least in Figures 1 to 4 show four positions along the elongated element in which the density or humidity value is maximum, which define corresponding capsules.
[0049] The capsule could also be moved radially with respect to the longitudinal axis of the capsule. For the sake of simplicity, the radial movement is not considered here.
[0050] In order to determine the presence of a capsule in the elongated element, it is possible to consider indifferently both the density profile and the humidity profile, i.e. the first or the second profile. Without loss of generality, it is considered that the determination of the presence of the capsule is achieved by processing only the density profile.
[0051] Elongated elements have been experimentally inspected that are called FILTER 24 that are 108 mm in length, comprising a plurality of portions of a predetermined length joined together, each comprising a respective capsule made of non fibrous material with which a corresponding ideal reference position is associated. Determining the intactness of a capsule inserted into an elongated element comprising a plurality of portions has to be repeated for each capsule, or for the corresponding research zones or acceptability zones along the elongated element in which the capsules are provided.
[0052] If the capsule is present and is analysed further, the inspection unit associates with each capsule quality features thereof, such as intactness, and places the quality features at the disposal of the control unit of the machine, if the inspection unit is in line, in such a manner that the control unit of the machine can reject the elongated element with the defective capsule, if necessary.
[0053] We have said that the first and the second profile are compared with a respective first and second threshold reference, established dynamically. To establish the first threshold reference by statistical processing of the first profile an average reference profile of the first profile is established and with this average reference profile a first tolerance reference band is associated in which the average reference profile is comprised, bounded by a minimum limit profile and by a maximum limit profile, which are a function of the average reference profile.
[0054] In particular, the minimum and maximum limit profile of the first tolerance reference band are a function of both

the average reference profile of the first profile and of the standard deviation of the first profile, calculated from this predetermined number of elongated elements inspected previously, according to the following formulas:

Formula 3

minimum limit profile =

average reference profile of the first profile – 3 * standard deviation

Formula 4

maximum limit profile =

average reference profile of the first profile + 3 * standard deviation

[0055] What has been said about the first density profile, applies in the same manner to the second humidity profile, which can be processed simultaneously or separately with respect to the density profile. The second threshold reference is established by a statistic of the second profile, calculating an average reference profile of the second profile obtained from this predetermined number of filtering elements inspected previously. A second tolerance reference band, bounded by a minimum limit profile and by a maximum limit profile according to the average reference profile, is associated and comprises the average reference profile of the second profile.

[0056] Also the minimum limit profile and minimum limit profile of the second band are a function of both the average reference profile of the second profile and of the standard deviation of the second profile obtained from this predetermined number of filtering elements inspected previously according to the following formulas:

Formula 5

minimum limit profile =

average reference profile of the second profile – 3 * standard deviation

Formula 6

maximum limit profile =

average reference profile of the second profile + 3 * standard deviation

[0057] The capsule, as will be explained better below, is intact only if the first profile is inside the first tolerance reference band and the second profile is inside the second tolerance reference band.

[0058] In Figures 3 and 4, the predetermined number of elongated elements inspected for the statistical determination of the first and second reference, respectively for the first profile and for the second profile, is 100. An inspection cycle comprises inspecting the profiles of the predetermined number of elongated elements, and i.e. 100, and at the end of each inspection cycle the threshold profiles calculated by statistical processing replace those calculated in the previous cycle.

[0059] In Figure 3 reference is made to density measurements and thus to the first profile. With 5 the average reference profile is indicated of the first profile. With 6 there is indicated the maximum limit profile, obtained as an average profile + 3 * standard deviation. With 7 the minimum limit profile is indicated, obtained as an average reference profile of the first profile - 3 * standard deviation. With 8 the profile of the maximums is indicated, as will be illustrated further on. With 9 there is indicated the profile of the minimums, as will be illustrated further on.

[0060] In Figure 4 reference is made to humidity measurements and thus to the second profile. With 10 there is indicated the average reference profile of the second profile. With 11 there is indicated the maximum limit profile, obtained as an average profile + 3 * standard deviation. With 12 there is indicated the minimum limit profile, obtained as an average reference profile of the second profile - 3 * standard deviation. With 13 there is indicated the profile of the maximums. With 14 there is indicated the profile of the minimums.

[0061] The first profile is obtained by sampling a signal that expresses the first measurable physical quantity and i.e. the density. A set plurality of samples are thus acquired, interpolated along the longitudinal extent of the elongated element, that enable the first density profile to be reconstructed. What has been said applies equally to the reconstruction of the second profile that is obtainable by the second measurable physical quantity and i.e. by the humidity.

[0062] Sampling of the signal of the first and/or the second measurable physical quantity is conducted in equidistant positions, each mm in the represented figures, of the longitudinal extent of the elongated element and along the entire elongated element and each ith sample of the first and/or of the second profile corresponds to a corresponding longitudinal ith position of the elongated element. For example, if the inspection is conducted in line during production and the elongated element advances with respect to the measuring sensor, an acquisition can be made at each machine revolution or at different intervals of time, provided sampling is carried out in equidistant positions. The control unit of the inspection unit or the control unit of the automatic machine that is able to supply the sampling command performs suitable processing on the machine speed and on the sampling instant to respect this constraint.

[0063] All the acquired samples of a number of inspected elements of an inspection cycle are stored in the inspection unit, both for the first and for the second profile. In particular, for each kth element inspected, each acquired ith sample of the first and/or second profile is stored associated with the corresponding ith position of the elongated element. A two-dimensional table of stored samples is thus stored, ordered by each inspected element "k" and by the position "i" of the sample in the element.

[0064] After inspecting the hundred elongated elements of the inspection cycle, the stored samples are processed and the average reference profile of the first and/or the second profile can thus be calculated. In each ith position an average ith sample is calculated that is obtained from "i" samples of all the inspected elements of the first profile and/or of the second profile stored in the ith position, and the average reference profile is reconstructed by interpolating this plurality of average ith samples. In Figure 3 and in Figure 4, we have said that respectively with 5 there is indicated the average reference density profile, whereas with 10 there is indicated the average reference humidity profile.

[0065] Standard deviation of the first profile and/or of the second profile is like what has been said above, calculated at the end of the inspection cycle. In each ith position an ith standard deviation is calculated obtained from ith samples of all the inspected elements of the first profile stored in the ith position, and standard deviation is obtained by interpolating said plurality of standard ith deviations. At the end of each inspection cycle, each average ith sample and standard ith deviation replace the deviations calculated in the previous cycle. The minimum limit profile and maximum limit density profile and humidity profile of Figures 3 and 4, respectively indicated by 7 and 6 and by 12 and 11, obtained by using Formulas 3 to 6 for each ith position, in which the average ith sample and the standard ith deviation are calculated.

[0066] In Figures 3 and 4 there are also dedicated the respective profiles of the density minimums and maximums (indicated with 9 and 8) and of the humidity minimums and maximums (indicated with 14 and 13), obtained by considering in each ith position respectively the minimum ith value and the maximum ith value recorded in all the acquired samples. Considerations related with the profile of the minimums and with the profile of the maximums are supplied below.

[0067] As said before, the profiles of Figures 3 and 4 refer to elongated elements containing four capsules but the processing of the profiles for each capsule can also be made only in the zone of the elongated element in which, according to specifications established a priori, the capsule has to be present and/or in an acceptable position, ie. in the research zone and/or acceptability zone.

[0068] It is advantage to reconstruct the profiles from values that are sampled only in some portions of the longitudinal extent of the elongated element, inasmuch as it increases the processing speed of the inspection method. For this reason, in the Figures that we shall take into consideration, density and humidity profiles are shown only at the research zones along the entire extent of the elongated element.

[0069] Figures 5 and 6 shown the density profile 2 and the humidity profile 4 of the elongated element with broken capsules two and four, superimposed on the tolerance limits calculated according to the method of the present invention, in particular the average density profile 5 and humidity profile 10, the maximum limit density profile 6 and humidity profile 11 and the minimum limit density profile 7 and humidity profile 12 are superimposed on the density profiles 2 and humidity profiles 4.

[0070] It should be noted in Figure 5, that the elongated element would have capsules two and four intact, inasmuch as the density profile 2 is inside the reference band identified by the minimum limit profile 7 and by the maximum limit profile 6. Otherwise, the humidity profile of Figure 6 correctly identifies capsules two and four as capsules that are not intact, inasmuch as the humidity profile is not inside the corresponding tolerance reference band, but is outside at least in some portions of the research zone. In other words, in order to be able to be intact after the capsule is inspected, the first and also the second profile have to be entirely comprised in the tolerance reference band.

[0071] It is observed that, even if only the first or the second profile can be analysed to identify the presence of a capsule, both the first and the second profile have to be examined for the purposes of determining intactness. In fact, by analysing just one measurable parameter, i.e. the density, the capsules would have erroneously been considered to be intact. On the other hand, the humidity analysis correctly identifies the non intactness of a capsule. From what has been said so far, it is noted that the statistical processing of the first and of the second profile enables capsules that are not intact to be identified very simply in an elongated element. In fact, the first threshold profile and the second threshold profile, associated with a reference band calculated dynamically by statistical processing, are always able to adapt to the type of elongated elements considered and to great variability in the weight of the elongated element and/or of the capsule. It is therefore not necessary, during on-line production, to perform demanding operations of reconfiguring of the detection sensors or of the parameters of these sensors, inasmuch as the inspection unit is able to adapt itself to the properties of the samples that are fed to the inspection unit and are to be inspected, except for a configuration transient during a first acquisition cycle of the predetermined number of elongated elements.

[0072] As the maximum and minimum reference profile of the tolerance band are established dynamically and are a function of the average profile of the profiles, which is also established dynamically, the inspection of the elongated elements is able to adapt to properties of each elongated element that are not foreseeable a priori, for example a change of production batch. Further, the more similar the specifications of a production batch are to the specifications of the next production batch, the more the inspection method will be able to adapt swiftly to the new batch.

[0073] For inspections performed on line, the importance has been seen experimentally of always processing two different measurable parameters, inasmuch as the analysis of only a first or second profile could erroneously determine capsules as being intact that are not intact.

[0074] In order to make the inspection method of the present invention even more effective, the first profile and the second profile are moved to the ideal reference position of the capsule along the elongated element. Similarly to what has been said previously, the first threshold reference is established by statistical processing of the first profile 2 and the second threshold reference is established by statistical processing of the second profile 4, but the statistical processing of the first profile 2 and of the second profile 4 is performed on moved profiles of the previous inspection cycle.

[0075] If we then go back to considering Figures 3 and 4, it is noted that near the maximums of the average density profile of Figure 3, the profile of the maximums 8 is spaced away from the profile 6, constructed as a function of the average profile and of the standard deviation according to Formula 4. Similarly, near the changes of slope that are different from those that identify the maximums, the profile of the minimums 9 is far from the profile 7 constructed as a function of the average profile and of the standard deviation according to the Formula 3. In the other zones on the other hand, the profile of the maximums 8 is near the profile 6 and the profile of the minimums 9 is near the profile 7.

[0076] If the humidity profile of Figure 6 is now observed, also the profile of the maximums 13 is spaced away from the profile 11, and the profile of the minimums 12 is fairly spaced away from the profile 14.

[0077] An even more precise definition of the limits of the tolerance band is obtained if the disturbance is eliminated that is due to the identified position of the capsule along the elongated element, which influences the form of the density and/or humidity profile acquired. In order to eliminate this disturbance, the first profile 2 and the second profile 4 are moved by superimposing the identified position of the capsule to the ideal reference position in which the capsule should have been located according to reference specifications.

[0078] The movement is performed for each profile acquired that is stored moved and the calculation of the average profile and of standard deviation is based on moved profiles and not on profiles as originally obtained. Possible disturbance is thus eliminated in statistical processing that is due to movement of the profile from the ideal position. In other words, the calculation of the average profile and of standard deviation is performed at the conclusion of the inspection cycle on profiles obtained during the inspection cycle itself, each moved profile realigned on an ideal position and then stored for statistical processing performed at the end of the acquisition cycle.

[0079] The first profile and the second profile obtained from the first physical quantity and from the second physical quantity are on the other hand used, just as acquired, to identify the position of the capsule in the elongated element but are moved, for the comparison respectively with the first threshold reference and the second threshold reference, established according to the statistical processing of the moved profiles, stored during the previous acquisition cycle.

[0080] In detail, for each inspected elongated element of an inspection cycle a first and a second profile is reconstructed by the ith samples acquired, as has already been illustrated previously with reference to non-moved profiles. By means of the thus reconstructed first or second profile the position of the capsule in the elongated element is identified.

[0081] The ith samples are, however, moved so as to make the ideal position of the capsule coincide with the identified position. The first and the second profile reconstructed from moved ith samples is used for comparing with the first threshold reference and the second threshold reference, obtained from moved profiles of the previous inspection cycle.

[0082] The ith samples are further stored. In this manner the average ith profile and the ith standard deviation are calculated according to Formulas 3 to 6 on moved "i" start samples. In fact, the two-dimensional table of the samples ordered for each inspected "k" element and for the "i" position of the sample in the element, stores the moved ith samples.

[0083] Similarly to what has been said before, only the research zone or acceptability zone is processed in which the presence of the capsule is expected.

[0084] If Figures 9 and 10 are now considered, wherein the reference profiles are calculated after the profiles have been moved, it is noted that the tolerance band constructed with the average profile 15, the maximum limit profile 16 and the minimum limit profile 17, using the average values and the standard deviations, is narrower, as it noted for the density profile of Figure 9 compared with the density profile of Figure 5. The profile of the maximums and the profile of the minimums are not shown as they are substantially superimposed on the maximum limit profile 16 and on the minimum limit profile 17. In Figure 10, similarly, the average profile 20 and the maximum humidity limit profile 21 and minimum humidity limit profile 22 are more suitable, inasmuch as they substantially coincide respectively with the profiles of the minimums and of the maximums.

[0085] In Figure 9, it is seen that the density profile 2 is outside the reference band identified by the maximum limit profile 16 and minimum limit profile 17, for positions of capsules two and four. Specifically, the density profile 2 of capsule four is superimposed on the maximum limit profile.

[0086] Capsules two and four are therefore not intact even by means of a density measurement whereas, as said before, with reference to Figures 5 and 6, they would be found to be non intact owing only to the humidity measurement.

[0087] The first threshold reference in association with the density shown in Figure 9 now expresses, after movement of the profiles, a stricter but more precise limit. The second threshold reference in association with the humidity shown in Figure 10, which already without moving the profiles, according to what was said in reference to Figure 6, was able to identify correctly a non intact capsule, all the more so, indicate the lack of intactness in capsules two and four.

[0088] Nevertheless, it is observed that the method of the present invention is even more advantageous if an elongated element is considered with capsules that are not intact, analysed a long time after the breakage of the capsules.

[0089] Figures 11 and 12 show the density profile 2 and the humidity profile 4 of the elongated element with broken capsules two and four analysed 10 days after the breakage in the capsule, superimposed on the maximum limit profile (6 for the density profile and 11 for the humidity profile) and minimum limit profile (7 for the density profile and 12 for the humidity profile) calculated according to Formulas 3 to 6 but without the step of moving the profiles for statistical processing. It is noted that the capsules would all have been considered to be intact, both using the density profile 2 and the humidity profile 4 with respect to the corresponding tolerance bands. The comparison between the density profile and the corresponding reference profile, the humidity profile and the corresponding reference profile would not have highlighted differences with respect to the reference profile.

[0090] The non intactness of capsules two and four would not have been detected. On the other hand, by applying the movement of the profiles, i.e. moving the first and the second profile in an ideal reference position, by calculating the average profile and the standard deviation from moved profiles, it is possible to identify the broken capsules two and four, even if the elongated element is analysed 10 days after breakage of the capsules. What has been said has been established by experiment, as shown in Figures 13 and 14. In fact it is noted that the density profile at the capsules in positions two and four falls outside the limits whereas the humidity profile never falls outside the limits. The elongated element is considered after inspection to contain non-intact capsules, as indicated by the analysis of the density profile.

[0091] Owing to the present invention, which establishes the first threshold reference and the second threshold reference by statistical processing and the movement of the profiles, and comparing the first moved profile and the second moved profile respectively with the first threshold reference and with the second threshold reference, it is thus possible to provide a very sensitive inspection method that not only enables the problem to be solved of making the inspection method invariant in relation to the type of elongated element inspected, but also with respect to the moment in which the inspection is conducted. For this reason, the inspection method according to the invention is advantageously usable not only in an on-line inspection unit but also and above all in an off-line inspection unit to which elongated elements to be inspected can be supplied even some time after production.

[0092] This ensures great reliability in the very simple and cheap inspection method in as much as it does not require modifications to the configuration of the parameters of the sensors and the inspection unit does not need to be instructed in the physical properties of the production batches but it above all enables a reference profile to be obtained that is always appropriate, even over the long term.

Claims

1. Method for inspecting an elongated element for smoking articles, wherein the element is rod-shaped and is made of a fibrous raw material, comprising the steps of

    - obtaining at least a first profile (2) of a first measurable physical quantity, for example density, and a second profile (4) of a second measurable physical quantity, for example humidity, by means of at least one sensor interacting with the elongated element along the same elongated element;
    - processing at least one of the first profile (2) and the second profile (4) to determine the presence of at least one capsule made of non-fibrous material, for example an aromatising additive inserted inside the elongated element;
    - if the capsule is present, evaluating the intactness of the capsule, comparing the first (2) and the second profile (4) respectively with a first (16, 17) and second threshold reference (21, 22); **characterised in that** said method further comprises:

- moving the first profile (2) and/or the second profile (4) to an ideal reference position of the capsule along the elongated element;
- establishing, during the operational functioning, the first threshold reference (16, 17) by statistical processing of the first profile (2) and establishing the second threshold reference (21, 22) by statistical processing of the second profile (4);
- the first and second statistical processing being performed respectively on moved profiles of a preceding inspection cycle, defined by a predetermined number of inspected elements.

2. Method according to claim 1, wherein the step of establishing the first threshold reference (16, 17) by statistical processing of the first profile (2) comprises the steps of calculating an average reference profile (15) of the first profile (2) in the preceding inspection cycle and associating with said average reference profile (15) a first tolerance reference band (16, 17) in which said average reference profile (15) is comprised, bounded by a minimum limit profile (17) and by a maximum limit profile (16) as a function of said average reference profile (15) of the first profile (2); and wherein moreover/optionally the step of establishing the second threshold reference (21, 22) by statistical processing of the second profile (4) comprises the further steps of calculating an average reference profile (20) of the second profile (4) in the preceding inspection cycle and associating with said average reference profile (20) a second tolerance reference band (21, 22) in which said average reference profile (20) is comprised, bounded by a minimum limit profile (22) and by a maximum limit profile (21) as a function of the average reference profile (20) of the second profile (4).

3. Method according to claim 2, wherein the step of evaluating the intactness of the capsule comprises comparing the first profile (2) with the first tolerance reference band (16, 17) and the second profile (4) with the second tolerance reference band (21, 22), the capsule being intact if the first profile (2) is inside this first tolerance reference band (16, 17) and the second profile is inside this second tolerance reference band (21, 22).

4. Method according to claim 2 or 3, wherein the minimum limit profile (17) and maximum limit profile (16) of said first band (16, 17) are a function of average reference profile (15) of the first profile (2) and of the standard deviation of the first profile (2) in the preceding inspection cycle, according to the following formulas:

$$\text{minimum limit profile} = \text{average reference profile of the first profile} - 3 * \text{standard deviation;}$$

$$\text{maximum limit profile} = \text{average reference profile of the first profile} + 3 * \text{standard deviation.}$$

5. Method according to claim 2 or 3, wherein the minimum limit profile (22) and maximum limit profile (21) of the second band (21, 22) are a function of average reference profile (20) of the second profile (4) and of the standard deviation of the second profile (4) in the preceding inspection cycle, according to the following formulas:

$$\text{minimum limit profile} = \text{average reference profile of the second profile} - 3 * \text{standard deviation;}$$

$$\text{maximum limit profile} = \text{average reference profile of the second profile} + 3 * \text{standard deviation.}$$

6. Method according to any preceding claim, wherein processing the first profile (2), or the second profile (4), for determining the presence of at least one capsule comprises the steps of: identifying the position of the capsule in the elongated element, and in particular wherein said identifying the position of the capsule comprises identifying a maximum value of the first profile (2), or respectively of the second profile (4) in said elongated element, the corresponding position of the maximum value in the elongated element corresponding to the position of the capsule, comparing said position identified with a minimum reference position and a maximum reference position comprising an ideal reference position, the capsule being present if the identified position is comprised in a research zone between the minimum reference position and the maximum reference position.

7. Method according to claim 6, wherein moving the first profile (2) and/or the second profile (4) to an ideal reference position comprises superimposing the identified position of the capsule on the ideal reference position, and wherein performing the statistical processing of the first profile (2) and of the second profile (4) on moved profiles comprises for each inspected elongated element of the preceding inspection cycle the steps of moving each first profile (2) and/or each second profile (4) in such a manner as to superimpose the identified position of the capsule on the ideal reference position, performing the statistical processing of the first profile and of the second profile on the basis of said moved profiles.

8. Method according to claim 7, as appended to claim 2, or as appended to claim 4 or 5, and comprising the further steps of storing each first profile moved and second profile moved and calculating said average reference profile (15; 20) of the first profile (2) and/or of the second profile (4) and/or said standard deviation of the first profile (2) and/or of the second profile (4) from the stored moved profiles.

9. Method according to any preceding claim, wherein obtaining a first profile (2) and/or a second profile (4) comprises acquiring a preset plurality of samples respectively of a first signal obtainable of the first measurable physical quantity and of a second signal obtainable of the second measurable physical quantity, and reconstructing the first profile (2) and/or the second profile (4) by interpolating this preset plurality of sampled values.

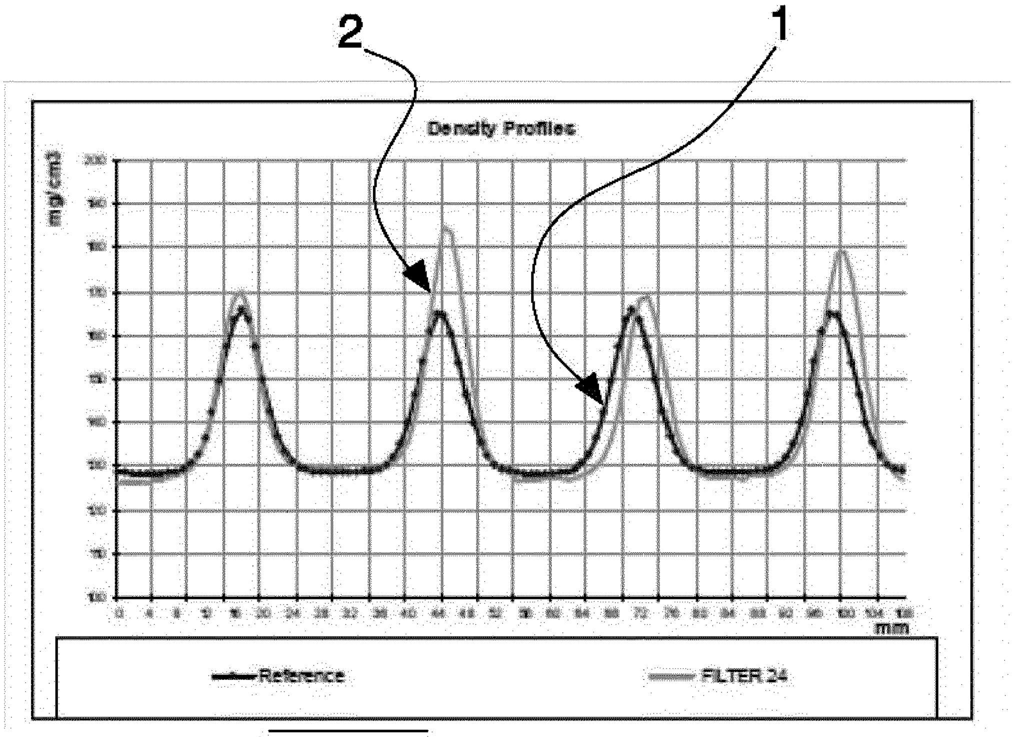
10. Method according to claim 9, and comprising performing this sampling in a preset plurality of equidistant positions along the longitudinal extent of the elongated element, each i-th sample of the first (2) and/or of the second profile (4) corresponding to a corresponding i-th longitudinal position of the elongated element.

11. Method according to claim 9 or 10, and further comprising the steps of: identifying a position of the capsule in the elongated element, moving the first profile (2) and/or the second reconstructed profile (4) by superimposing the identified position of the capsule on the ideal position; the method further comprising the step of storing, for each k-th inspected element of an inspection cycle, each acquired and moved i-th sample of the first (2) and/or of the second profile (4) associated with the corresponding i-th position of the elongated element.

12. Method according to claim 11, as appended to claim 2, wherein calculating an average reference profile (15) of the first profile (2) and/or an average reference profile (20) of the second profile (4) in the preceding inspection cycle comprises, in each i-th position, calculating an average i-th sample of the first profile (2) or of the second profile (4) obtained from i-th moved samples of the first profile (2) or of the second profile (4) that are stored in the i-th position, and reconstructing the average reference profile (15, 20) by interpolating this plurality of average i-th samples obtained from i-th samples of the first profile (2) or of the second profile (4) moved in the preceding inspection cycle.

13. Method according to claim 11, as appended to claim 4, or to claim 5, wherein calculating standard deviation of the first profile (2) and/or of the second profile (4) comprises, in each i-th position calculating a standard deviation i-th of the first profile and/or of the second profile obtained from i-th moved samples that are stored in the ith position of the first profile (2) and/or of the second profile (4), and reconstructing the standard deviation of the first profile and/or of the second profile by interpolating this plurality of i-th samples of standard deviation of the first profile (2) and/or of the second profile (4) moved in the preceding inspection cycle.

14. Inspection unit of an elongated element for smoking articles, wherein the element is rod-shaped and is made of a fibrous raw material, comprising one or more of detection sensors of a first measurable physical quantity and of a second measurable physical quantity from which a first profile and a second profile are respectively obtainable, which can be processed by a control device of the inspection unit for determining the presence of at least one capsule of non fibrous material, for example an aromatising additive, inserted inside the fibrous element using an inspection method according to any one of claims 1 to 13.


2
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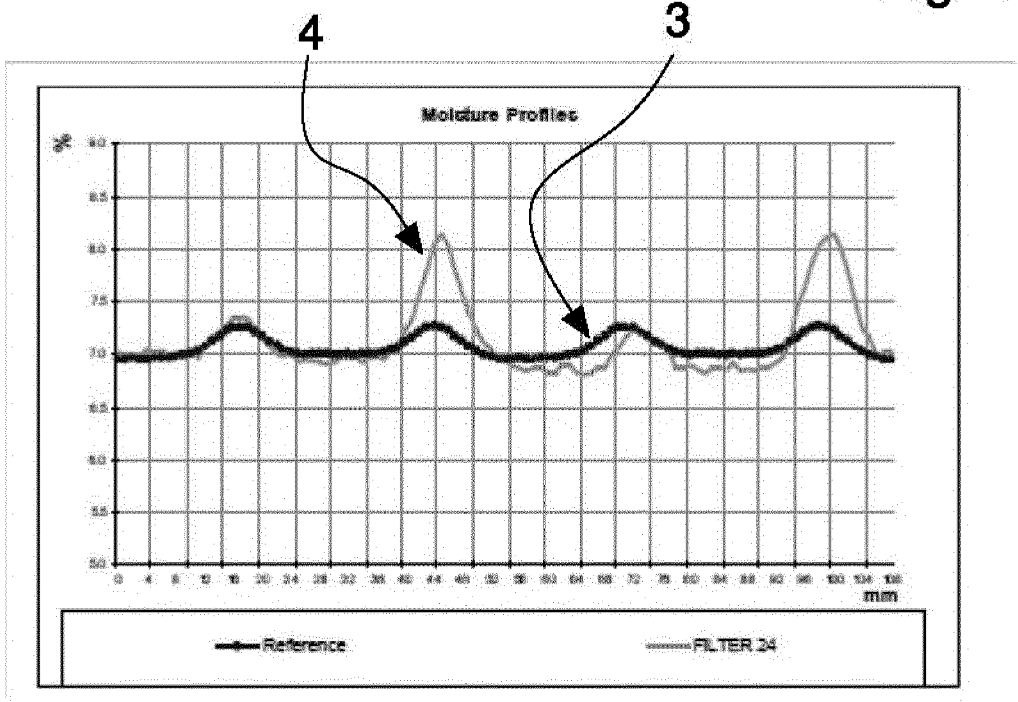
Density Profiles
mg/cm3
mm
Reference
FILTER 24

Fig. 1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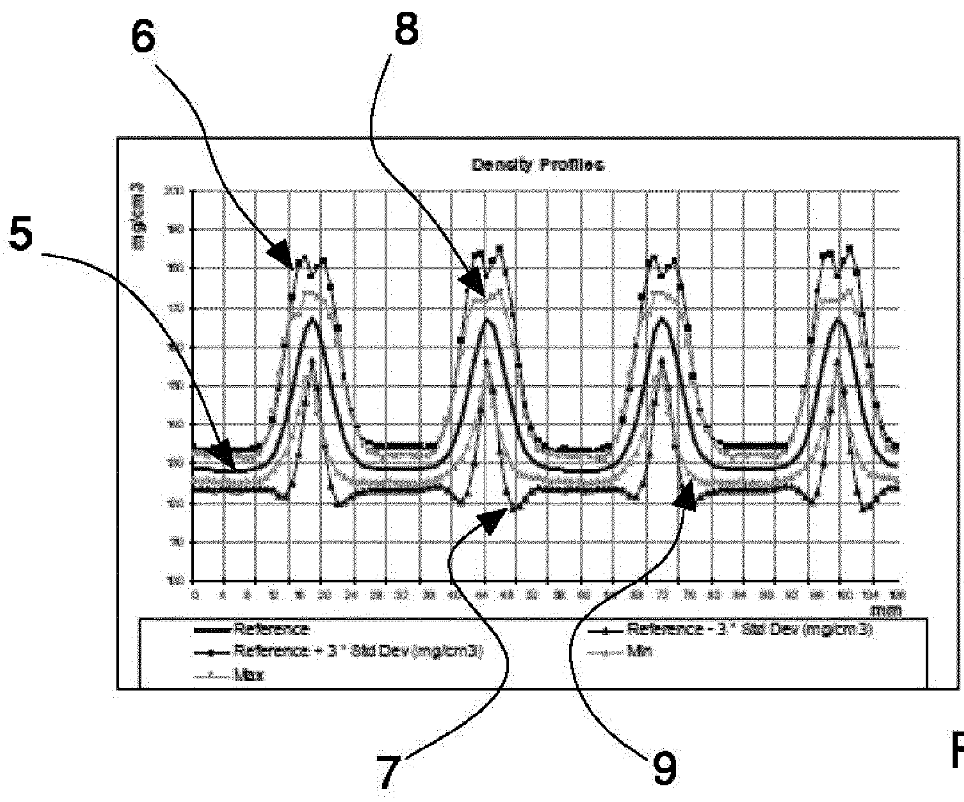
Moisture Profiles
%
mm
Reference
FILTER 24

Fig. 2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8
5
Density Profiles
mg/cm3
mm
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Max
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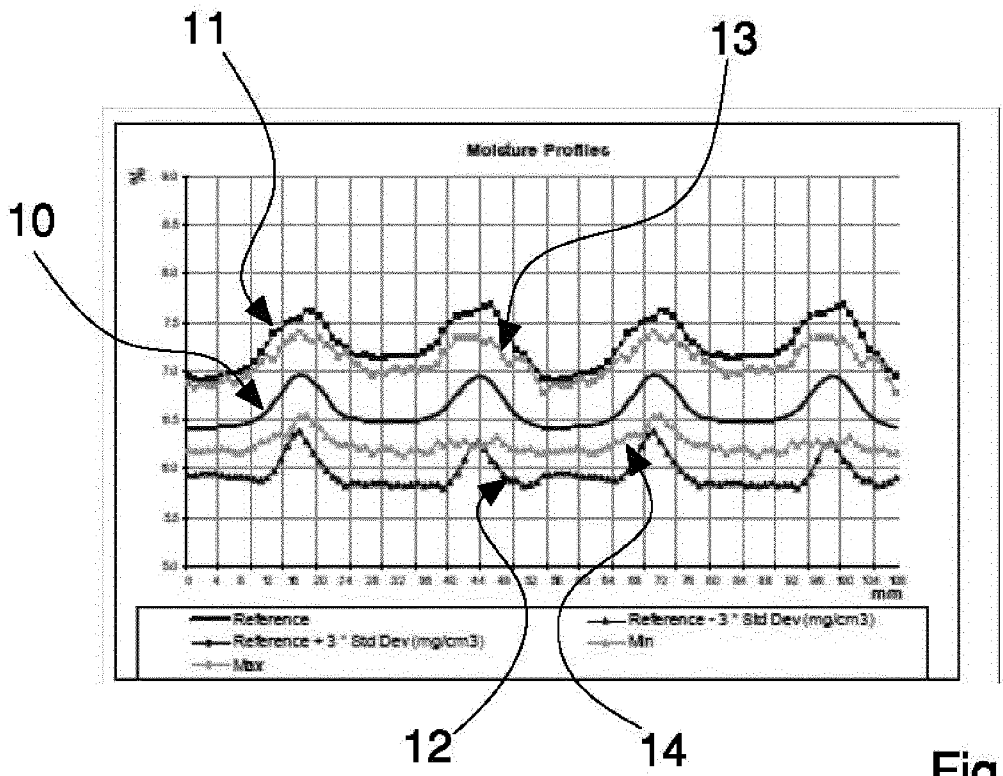
Min
7
9

Fig. 3


11
13
10
Moisture Profiles
%
mm
Reference
Reference + 3 * Std Dev (mg/cm3)
Max
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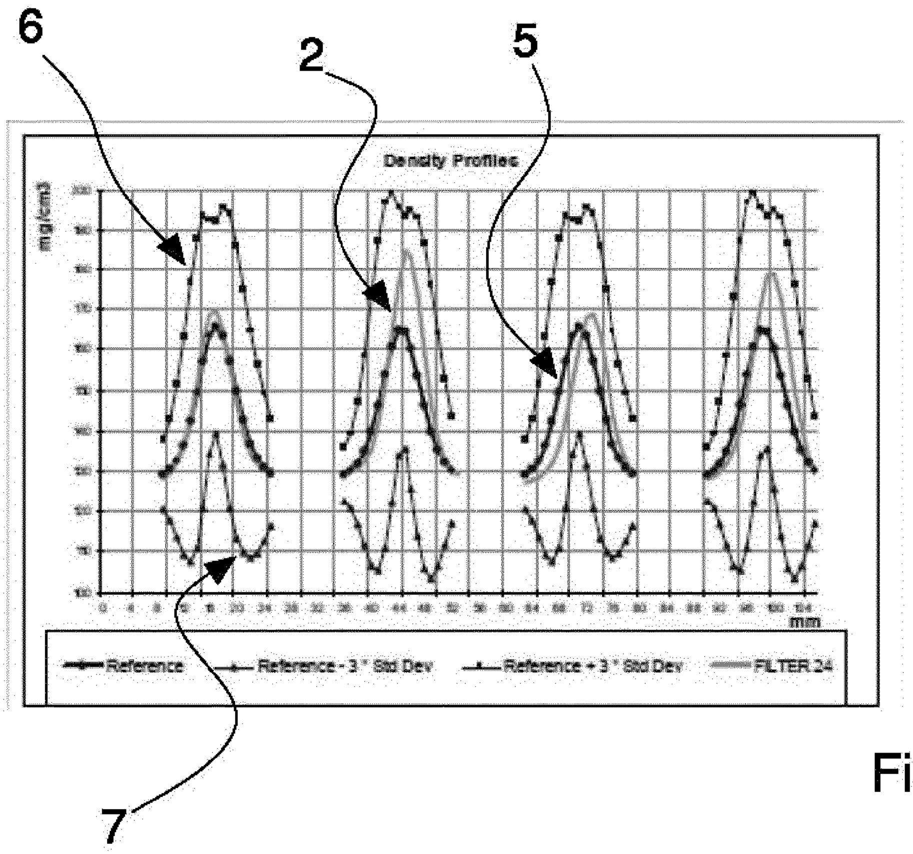
Min
12
14

Fig. 4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Density Profiles
mg/cm3
mm
Reference
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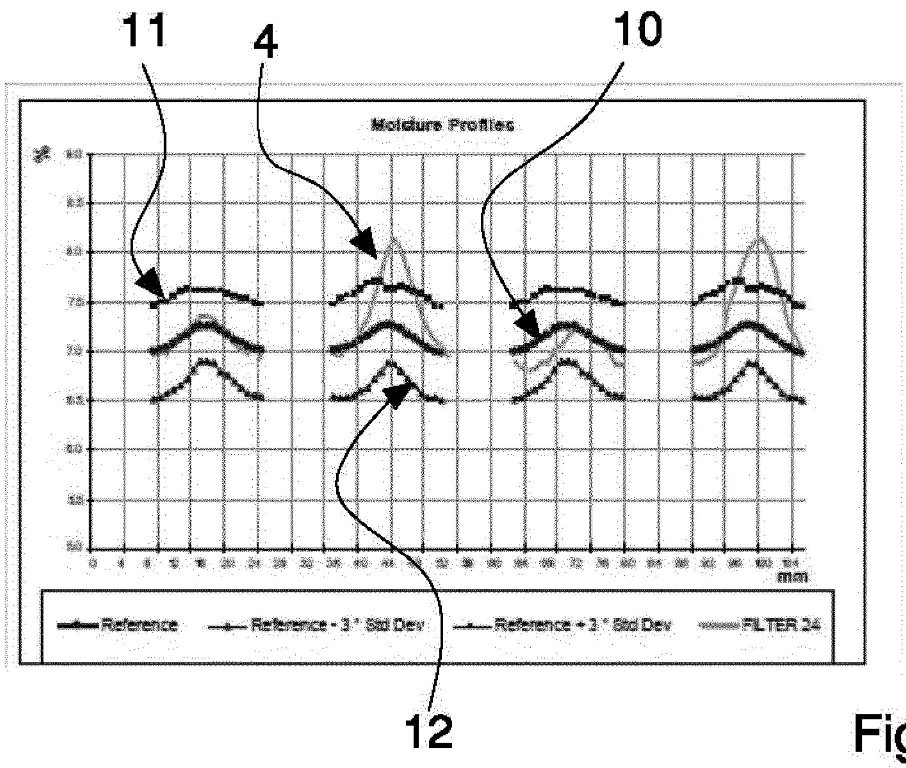
Reference + 3 * Std Dev
FILTER 24

Fig. 5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Moisture Profiles
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mm
Reference
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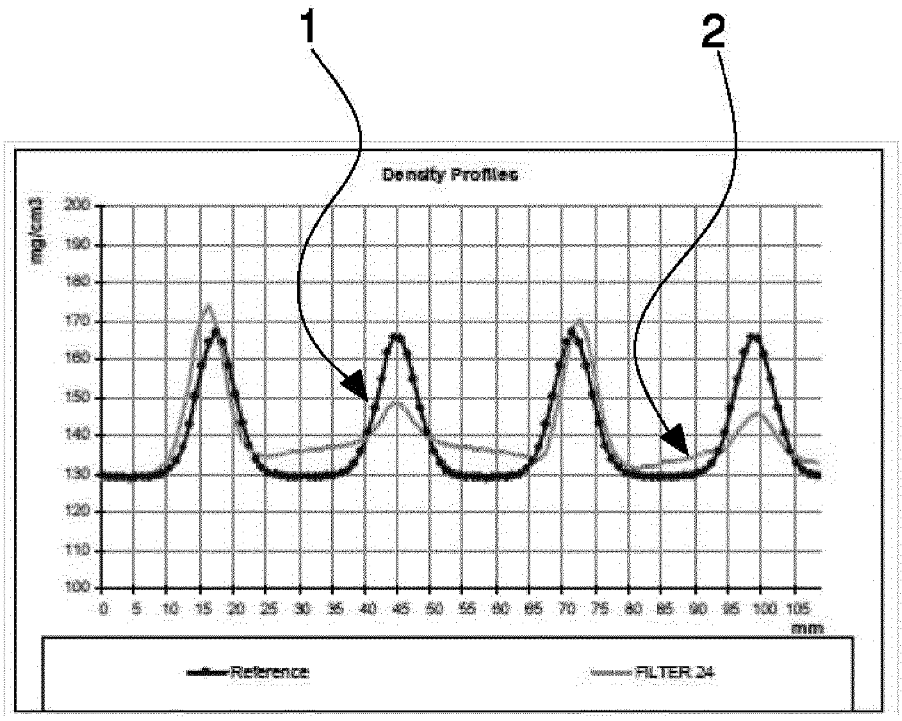
FILTER 24

Fig. 6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170
160
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130
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100
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mm
Reference
FILTER 24

Fig. 7

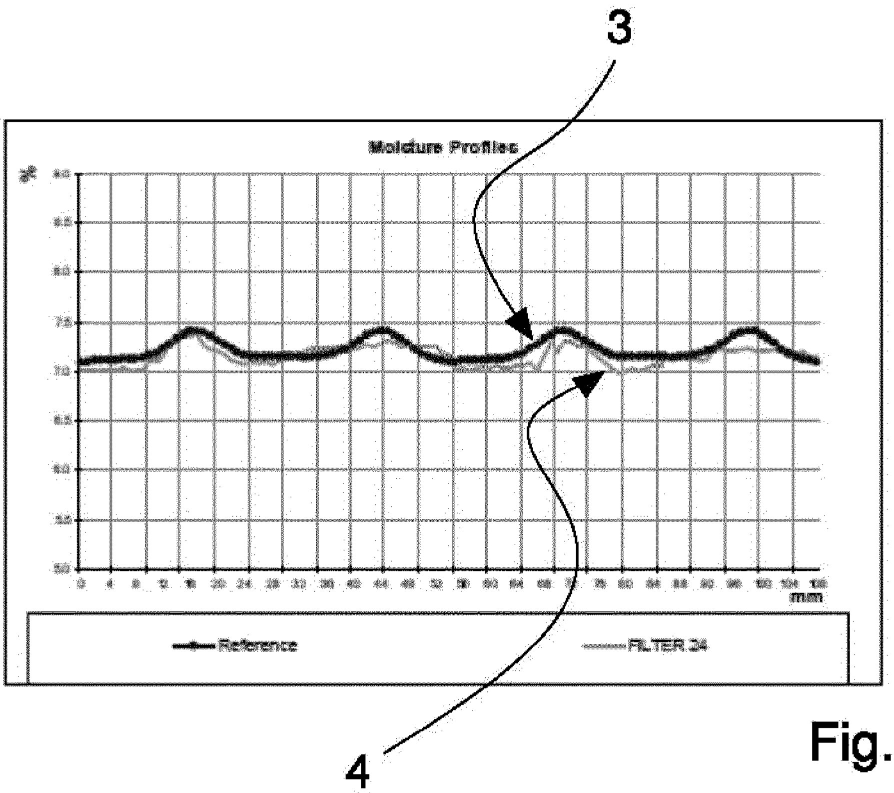
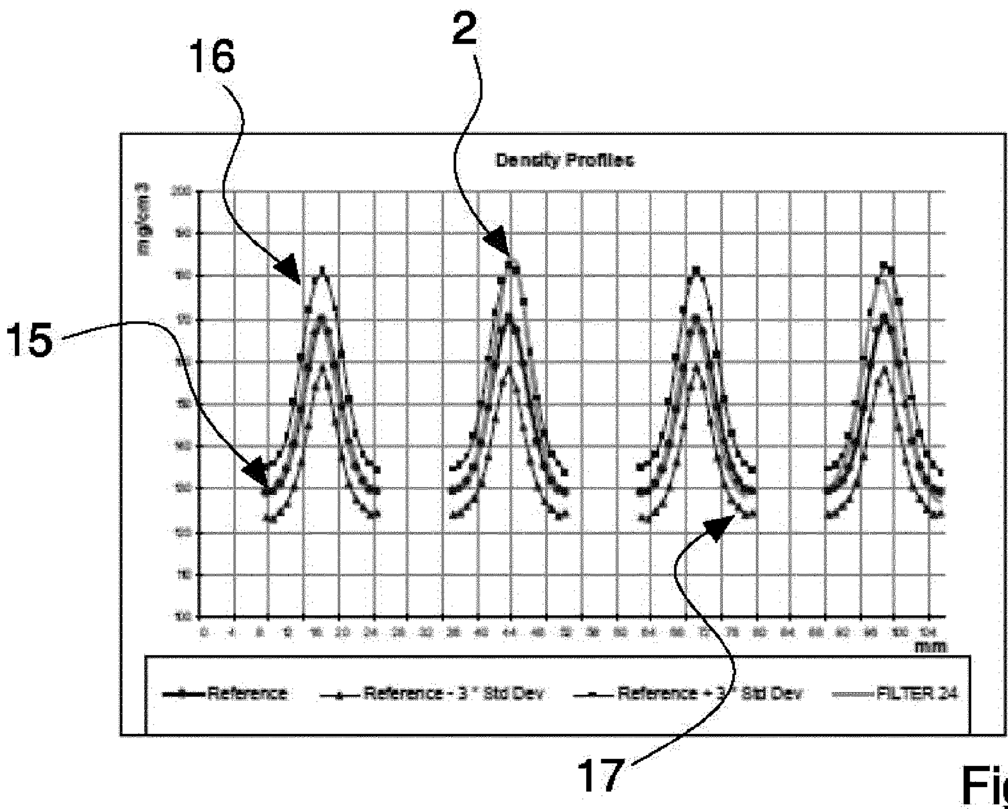

3
Moisture Profiles
%
mm
Reference
FILTER 24
4

Fig. 8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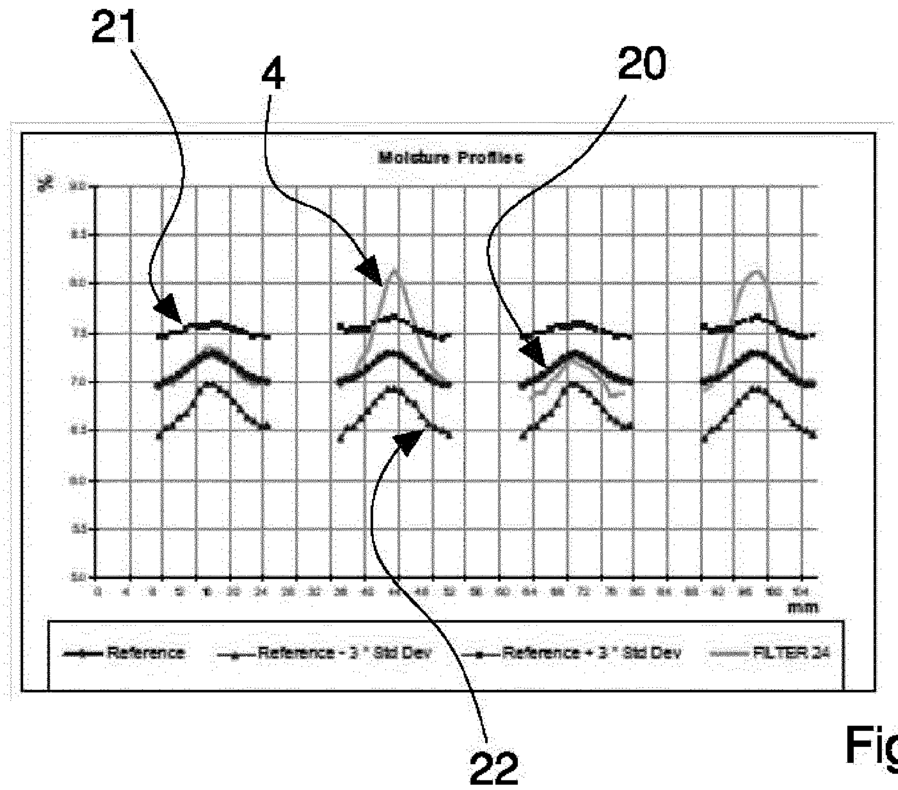
15
17
Density Profiles
mg/cm3
mm
Reference
Reference - 3 * Std Dev
Reference + 3 * Std Dev
FILTER 24

Fig. 9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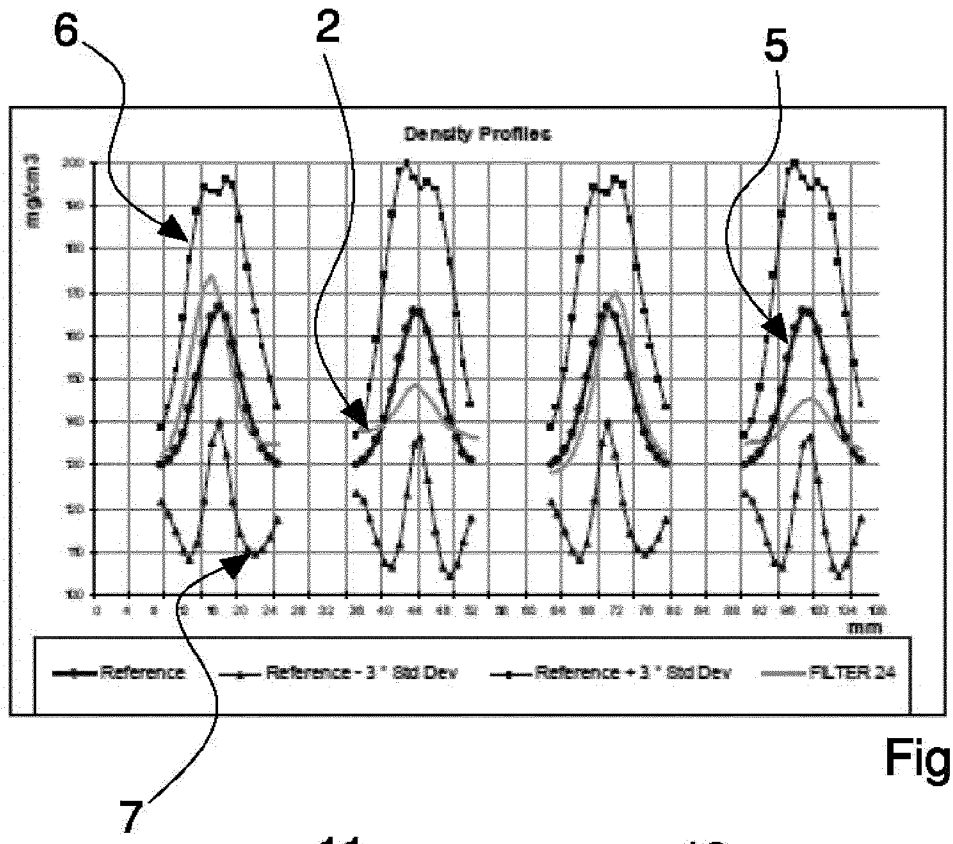
4
20
22
Moisture Profiles
%
mm
Reference
Reference - 3 * Std Dev
Reference + 3 * Std Dev
FILTER 24

Fig. 10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Density Profiles
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mm
Reference
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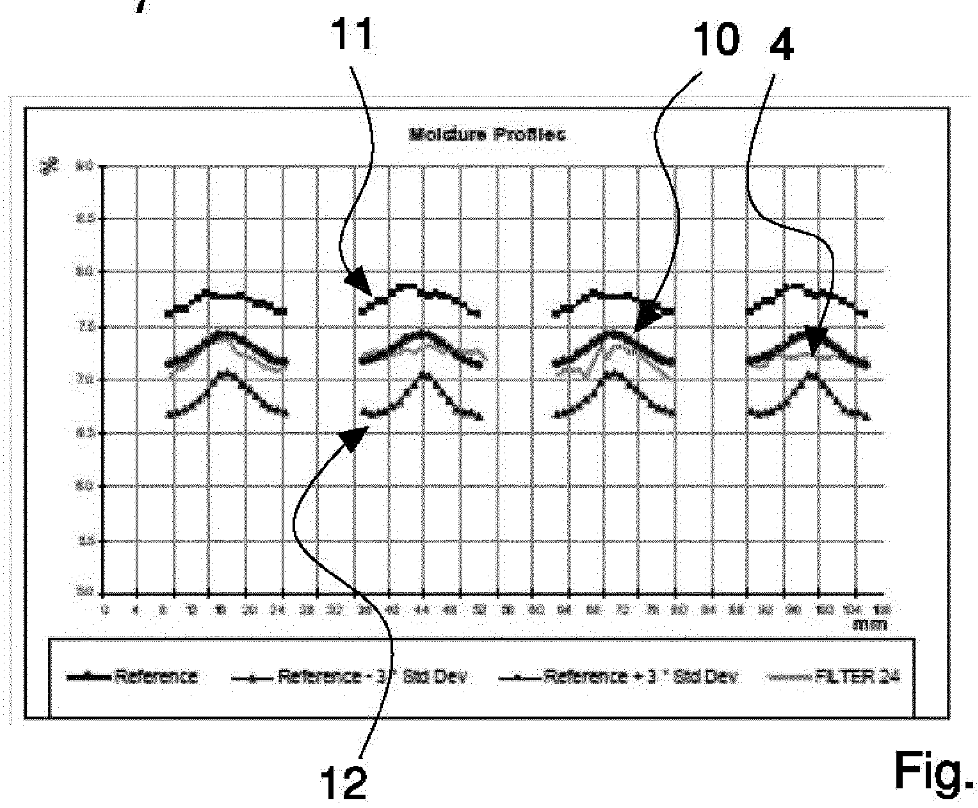
Reference + 3 * Std Dev
FILTER 24
7

Fig. 11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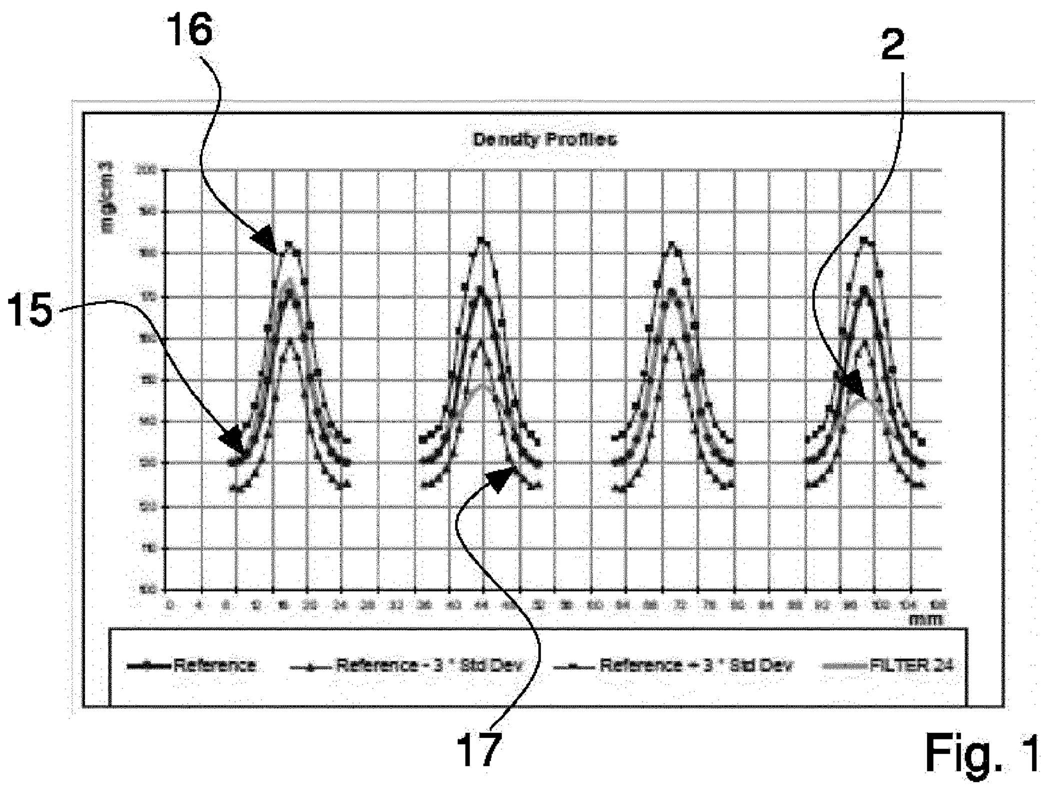
10
4
Moisture Profiles
%
mm
Reference
Reference - 3 * Std Dev
Reference + 3 * Std Dev
FILTER 24
12

Fig. 12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15
17
Density Profiles
mg/cm3
mm
Reference
Reference - 3 * Std Dev
Reference + 3 * Std Dev
FILTER 24

Fig. 13

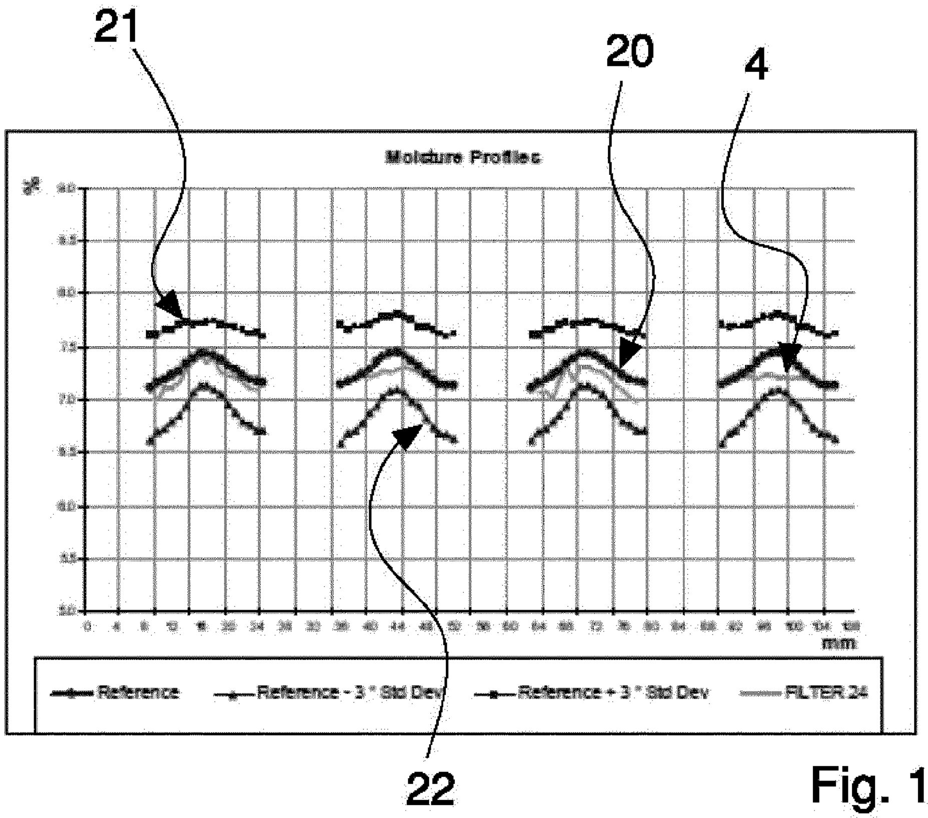
21
20
4
22
Moisture Profiles
%
mm
Reference
Reference - 3 * Std Dev
Reference + 3 * Std Dev
FILTER 24

Fig. 14

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2011083406 A **[0021]**