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(54) **DYSFUNCTIONAL EJECTION UNIT DETERMINATION IN INKJET PRINTING**

(57) The present invention relates to a method for establishing a list of dysfunctional ejection units, i.e. a list of ejection units in an inkjet printer that are to be discarded during printing of image data in order to obtain a better print quality. The method comprises the steps of: printing and scanning a first test pattern (9) wherein individual dots of a single ejection unit can be discerned; printing and scanning a second test pattern (8) with uniform gray-scale areas that are processed in a similar way as image data; determining a drop ejection characteristic of a single ejection unit from the scanned first test pattern; determining an optical profile of the second test pattern in a direction of the array; composing a list of ejection units that yield dots outside a predetermined range; adding to the list the ejection units that show a deviating optical density compared to their direct environment, and passing the list of ejection units to the printer control software as a list of dysfunctional ejection units.

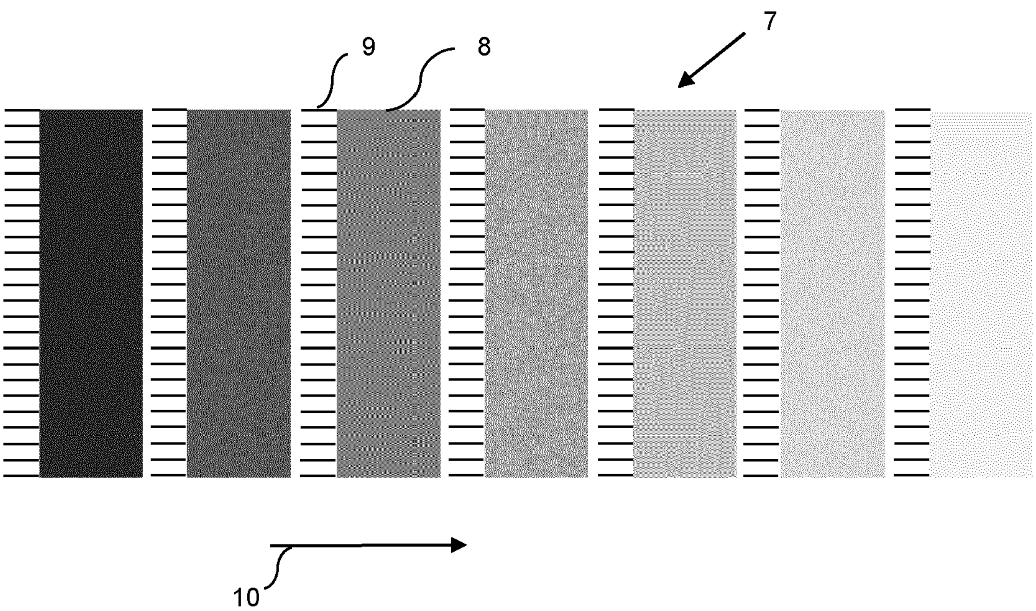

Fig. 2

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Description

FIELD OF THE INVENTION

[0001] The present invention generally pertains to a method for establishing a list of dysfunctional ejection units in an array of ejection units that are arranged for printing image data.

BACKGROUND ART

[0002] Inkjet printing is well-known for its use of an array of ejection units that move relatively to a substrate which is to receive the ejected ink drops. This results in columns of ink dots, rendering a printed image. Page-wide arrays (PWA) are known to span a full width of either sheets or a web of material that is moved underneath the arrays, such that the printed image is made in one pass, in contrast to multi-pass printing in scanning print head systems.

[0003] Unfortunately, it may happen that one of the ejection units, also referred to as nozzles, does not behave as required, which is particularly annoying when there is only one opportunity to provide an ink dot on a substrate position, such as with PWA. This is for example the case if the ejection of ink drops is blocked or if the ink drops are misdirected, which may be caused by residual ink at the end of the ejection unit or other pollution around a nozzle. In severe cases this may lead to inhomogeneity, such as streakiness, in uniform areas, whether in the form of light lines by a shortage of ink density or in the form of dark lines by an excess of ink density.

[0004] Many compensation algorithms are known to cover up these unwanted print quality disturbances. In these methods additional ink is applied by neighboring ejection units to make up for the ink deficit or less ink is applied to prevent the excess ink. However, in all cases it is necessary to determine which ejection unit causes the inhomogeneity. In general, this is done by checking an individual characteristic of an ejection unit, such as by an optical determination of the position of a dot that results from actuating the ejection unit. Other methods comprise a residual acoustic wave analysis for ejection units comprising a piezo-electric actuator and an optical measurement of the ink drop in flight towards the substrate. In particular, the angle of the drop trajectory is known to be relevant for the observed streakiness.

[0005] However, it was found by the inventors that something was missing in the known methods for a correct determination of the ejection units that needed to be compensated for their dysfunctional behavior. They found out that if the right nozzles could be determined, the level of streakiness could be substantially reduced and thus the print quality be enhanced. Thus, the object of the present invention is to improve the establishment of the list of nozzles that is passed to the algorithm for compensation.

SUMMARY OF THE INVENTION

[0006] In an aspect of the present invention, a method according to claim 1 is provided. This method comprises a second test pattern of uniform grayscale areas in addition to a first test pattern with individual dots or lines of dots stemming from a single ejection unit. Grayscale refers as usual to a contone definition of an ink density, ranging from no ink to a maximum density, and is applicable for any individual ink color. These test patterns are processed in a similar way as image data in a printing process, including a halftoning process, wherein a pattern of ink dots is derived to render the grayscale. Halftoning in this case refers to any method wherein a contone level is converted to a control signal for one or more ink drop sizes, which are defined by a number of discrete levels. For example, in a print process using two dot sizes, three discrete levels are discerned, each for one drop size. The advantage of the second test pattern is that the behavior of ink dots in relation to the neighboring ink dots is included in determining how the use of a particular ejection unit contributes to the print quality. An ejection unit is dysfunctional if the print quality improves after application of the compensation algorithm for that ejection unit. It was found that both the position of a nozzle on the nozzle plate and the properties of the substrate play a role in the resulting optical density, which should be as uniform as possible for these patterns. It is noted that ink drops that result in dots directly neighboring each other, are not applied simultaneously due to an offset of the nozzles in the transport direction of the substrate. Thus, a first drop arrives at an empty substrate, whereas a second drop, neighboring the first one, arrives at the substrate where the first drop is already present.

[0007] Furthermore, the behavior of the ink after having landed on the substrate depends both on the interaction between the substrate and the ink and the interaction between a freshly applied ink drop and the earlier applied ones. These aspects of the ink behavior can only be determined from a collective application, in contrast with the individual application as in the previously used test patterns. The interpretation of the optical profile, which is the progress of the optical density over the width of the uniform printed pattern, is based on a peak analysis in this profile. Surprisingly it was found that ejection units with individual characteristics within predefined boundaries were still causing a certain amount of streakiness that could be resolved by including them in the list of dysfunctional nozzles and thus be compensated by transferring ink to neighboring nozzles.

[0008] In an embodiment, the status of the ejection units is monitored during the printing of image data in order to keep the list of dysfunctional ejection units as actual as possible. For this purpose, additional patterns are applied outside an area where the image is printed. The patterns do not have to involve all ejection units at the same time, but may select a number of ejection units after one image and select another number of units after a next image. Also the pattern may vary during the print process. The determined amount of changes may also be used to trigger a further application of the full first and second test patterns.

[0009] Although it is also possible to derive a list of dysfunctional nozzles from the second test pattern only, it is preferable to use both test patterns. In that way, the application frequency of the second test pattern, which costs some substrate area, can be kept relatively low, in the order of once every 200 images.

[0010] The present invention is particularly useful to be embedded in an inkjet printer for printing image data on a substrate, the printer comprising a processing unit for controlling the printer, wherein the processing unit is configured to perform the invented method.

[0011] In an embodiment, the list of dysfunctional ejection units depends on the type of substrate. Since it was found that the behavior of the ink after landing on the substrate influences the occurrence of streakiness, the list of dysfunctional ejection units is also dependent on the type of substrate. Perhaps superfluously, it is noted that it is common practice to stop using a dysfunctional nozzle after having determined that its use does not contribute to the print quality.

[0012] Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating embodiments of the invention, are given by way of illustration only, since various changes and modifications of the invention will become apparent from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying schematical drawings which are given by way of illustration only, and thus are not limitative of the present invention, and wherein:

Figure 1A	shows a test pattern for individual ejection unit behavior;
Figure 1B	shows a possible result of printing the test pattern of Fig. 1A;
Figure 2	shows a test pattern for collective ejection unit behavior according to the present invention;
Figure 3	shows an optical profile for determination of dysfunctional ejection units;
Figure 4	is a schematic drawing of a page-wide printer wherein the invented method is applied.

DETAILED DESCRIPTION OF EMBODIMENTS

[0014] The present invention will now be described with reference to the accompanying drawings, wherein the same reference numerals have been used to identify the same or similar elements throughout the several views.

[0015] Figure 1A shows a conventional pattern 1 for determining the status of the ejection units. The individual bars 2 are printed by a single ejection unit. These ejection units are staggerdly arranged in the direction 3. Figure 1B shows a possible result 4 after printing. One ejection unit is blocked, resulting in a missing bar 5 and one is ejecting its ink drop in an angle towards the side, resulting in a misplaced bar 6. The corresponding ejection units are placed in a list of dysfunctional ejection units for which a compensation algorithm is invoked. The dysfunctional units themselves are not used for further printing.

[0016] Figure 2 shows a test pattern 7 according to the invention. A number of grayscale areas 8 are processed in a similar way as image data and printed on a receiving medium. A ruler 9 is added to locate a number of the ejection unit that contributes to the optical density in the grayscale area. In a page-wide printer this pattern is printed with a relative movement of the print head array to the receiving medium in the direction 10. In a scanning-type printer, the direction of the pattern is rotated 90 degrees relative to the transport direction.

[0017] Figure 3 shows a result of an optical density measurement of one of the grayscale areas 8 for a printer with an array of 1200 nozzles per inch. The measurement is done using an image quality sensor that scans the printed images. The optical resolution of the sensor is insufficient to resolve individual ejection units, but the progress of the ink density can be measured. The horizontal axis 11 shows the ejection unit number as determined from the ruler 9. In this example, three peaks 12 are identified as positions where a deviating optical density is found, using a commonly available peak analysis algorithm, such as scipy.signal.find_peaks in a Python software environment. Using the individual nozzle characteristics as determined from pattern 4, the ejection unit having the largest deviation from its expected position is determined as dysfunctional and added to the list.

[0018] A print system in which a method according to the present invention may be suitably used is described with reference to the appended schematic drawing shown in Figure 4. This print system is arranged for printing sheets, but the method may equally well be applied in a print system for printing web materials or rigid media.

[0019] Figure 4 shows a sheet of a receiving medium, P, being transported in a direction for conveyance as indicated by the arrows 50 and 51 with the aid of transportation mechanism 14, which is a driven belt system comprising one or more belts. Alternatively, one or more of these belts may be exchanged for one or more drums. A transportation mechanism may be suitably configured depending on the requirements (e.g. sheet registration accuracy) of the sheet transportation in each step of the printing process and may hence comprise one or more driven belts and/or one or more drums. For a proper conveyance of the sheets of receiving medium, the sheets need to be fixed to the transportation mechanism. The way of fixation is not particularly limited and may be selected from electrostatic fixation, mechanical fixation (e.g. clamping) and vacuum fixation. This last one is preferred.

[0020] The printing process as described below comprises of the following steps: media pre-treatment (13, 16, 17, 18), image formation (110), drying and fixing (20) and optionally post treatment (not indicated).

[0021] A media pre-treatment is applied to improve the spreading and pinning of the ink on the receiving medium P, in particular on slow absorbing media, such as machine coated media, prior to printing an image on the medium. In Figure 4 a pre-treatment module is shown comprising a pre-heating unit 13, for example a radiation heater, a roller coating unit with two rollers 16, 17 providing an aqueous pre-treatment liquid to the coated printing paper P from storage tank 15, and a drying member 18 that reduces the quantity of the water content in the applied coating. Each surface of the double rolls 16, 17 may be covered with a porous resin material such as sponge. Alternative methods of application of a pre-treatment liquid include an ink-jet application, a curtain coating and a spray coating. A roller coating method, as in Figure 4 , is preferable because this coating method applies the pre-treatment liquid homogeneously to a recording medium. In addition, the amount of the applied pre-treatment liquid with a roller or with other means to a recording medium can be suitably adjusted by controlling the physical properties of the pre-treatment liquid, the contact pressure of a roller in a roller coater to the recording medium and the rotational speed of a roller in a roller coater which is used for a coater of the pre-treatment liquid. From the viewpoint of drying uniformity, the application of a pre-treatment liquid to the entire surface of a coated printing paper is preferable, since application to a limited portion, such as a printed portion of the medium, may lead to unevenness between an application area and a non-application area caused by swelling of cellulose contained in the coated printing paper, in particular in the case of an aqueous pre-treatment liquid.

[0022] The step of image formation 110 is applied by four ink jet marking devices 111, 112, 113, and 114, positioned above the belt transporting the receiving medium P. Each device is as wide as the width 52 of the medium, thus making lateral movements of the devices during printing unnecessary. The devices are provided with ink in the colors cyan, magenta, yellow and black to produce a full color print using a CMYK subtractive color mixing scheme. The digital signals, or print signals, to control the individual liquid discharge elements of the marking devices are composed by the control module 30 from image data 25 using a high speed connection 32. An ink jet marking device as indicated above is also known as a page-wide array (PWA) and comprises a number of print heads wherein the discharge elements are also referred to as print elements, ejection units or nozzles, a nozzle being the part of a print element where the ink drops originate. Ink is supplied to the individual print elements through a channel in a print head. Not shown is a maintenance position wherein the marking devices are brought for flushing, purging and wiping the devices.

[0023] In addition to the staggered arrangement of nozzles within a print head, the print heads have a staggered arrangement to provide a PWA with nozzles which are substantially equidistant in the length direction of the inkjet marking device. This configuration may provide a redundancy of nozzles in an area where the inkjet heads overlap. Thus the arrangement of nozzles is not in a straight line, which causes the ink drops in a row perpendicular to the transport direction to be not simultaneously discharged. This is considered to be one of the reasons a procedure as presented in the present invention needs to be executed for all process colors individually.

[0024] Optionally, the image formation may be carried out while the receiving medium P is temperature controlled. For this purpose a temperature control device 19 may be arranged to control the temperature of the surface of the transportation mechanism underneath the inkjet marking module 110. The temperature control device 19 may be used to control the surface temperature of the receiving medium P, for example in a range of 30°C to 60°C. The temperature control device 19 may comprise heaters, such as radiation heaters, and a cooling means, for example a cold blast, in order to control the surface temperature of the receiving medium within said range. Subsequently and while printing, the receiving medium P is conveyed to the downstream part of the inkjet marking module 110.

[0025] After an image has been formed on the receiving medium, the prints are dried and the image is fixed onto the receiving medium. Drying comprises the evaporation of solvents, including water, in particular those solvents that have poor absorption characteristics with respect to the selected receiving medium.

[0026] Figure 4 schematically shows a drying and fixing unit 20, which may comprise a heater, for example a radiation heater. After an image has been formed, the print is conveyed to and passed through the drying and fixing unit 20. The print is heated such that solvents, in the present embodiment to a large extent water, in the printed image evaporate. The speed of evaporation and hence drying may be enhanced by increasing the air refresh rate in the drying and fixing unit 20. Simultaneously, film formation of the ink occurs, because the prints are heated to a temperature above the minimum film formation temperature. The residence time of the print in the drying and fixing unit 20 and the temperature at which the drying and fixing unit 20 operates are optimized, such that when the print leaves the drying and fixing unit 20 a dry and robust print has been obtained. The transportation mechanism 14 in the fixing and drying unit 20 may be separated from the transportation mechanism of the pre-treatment and printing section of the printing apparatus and may comprise a belt or a drum.

[0027] All the print processing steps sketched above influence the interaction between ink drops after having landed on the substrate and are considered to make it necessary to determine the dysfunctional nozzles, also known as inoperable ejection units, in their mutual environment. This is provided by the procedure as invented.

[0028] The invention being thus described, it will be obvious that the same may be varied in several ways. All such modifications of the present invention are intended to be included within the scope of the following claims.

Claims

1. A method for establishing a list of dysfunctional ejection units in an array of ejection units that are arranged for printing image data on a substrate, the image data being processed by a printer comprising printer control software, before being directed to the array of ejection units, the method comprising the steps of:

a. printing and scanning a first test pattern wherein individual dots of a single ejection unit can be discerned;
b. printing and scanning a second test pattern with uniform grayscale areas that are processed in a similar way as image data;
c. determining a drop ejection characteristic of a single ejection unit from the scanned first test pattern;
d. determining an optical profile of the second test pattern in a direction of the array;
e. composing a list of ejection units that yield dots outside a predetermined range from the result in step c.;
f. adding to the list the ejection units that show a deviating optical density compared to their direct environment from the profile in step d., and
g. passing the list of ejection units to the printer control software as a list of dysfunctional ejection units.

2. The method according to claim 1, wherein the second test pattern comprises a number of areas with various graytones, preferably 17 different graytones.

3. The method according to claim 1, wherein both the first test pattern and the second test pattern are printed on a single substrate.

4. The method according to claim 1, wherein during printing of image data, an additional pattern is printed to monitor changes in the ejection unit behavior.

5. The method according to claim 4, wherein a new set of first and second test patterns are printed if the number of changes in the ejection unit behavior is larger than a threshold.

6. An inkjet printer for printing image data on a substrate, the printer comprising a processing unit for controlling the printer, wherein the processing unit is configured to perform a method according to claim 1.

7. An inkjet printer according to claim 6, wherein a list of dysfunctional ejection units is used that depends on the type of substrate.

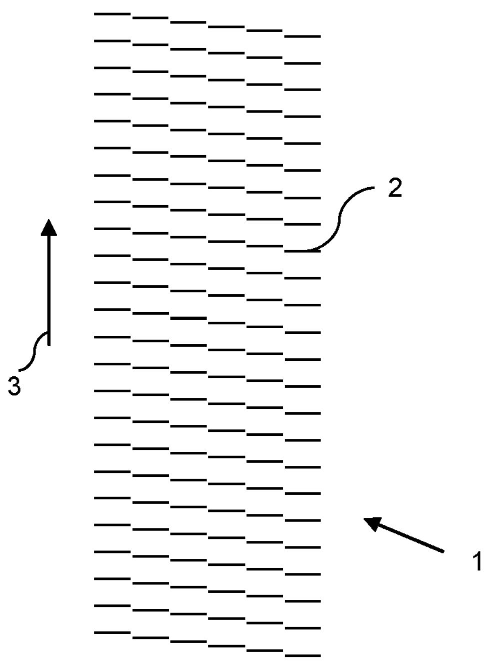

Fig. 1A

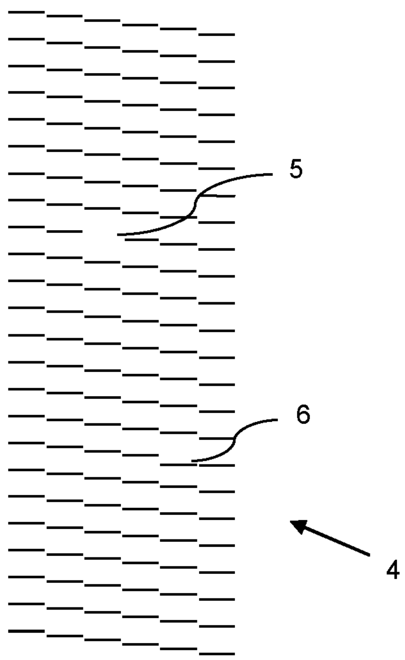

Fig. 1B

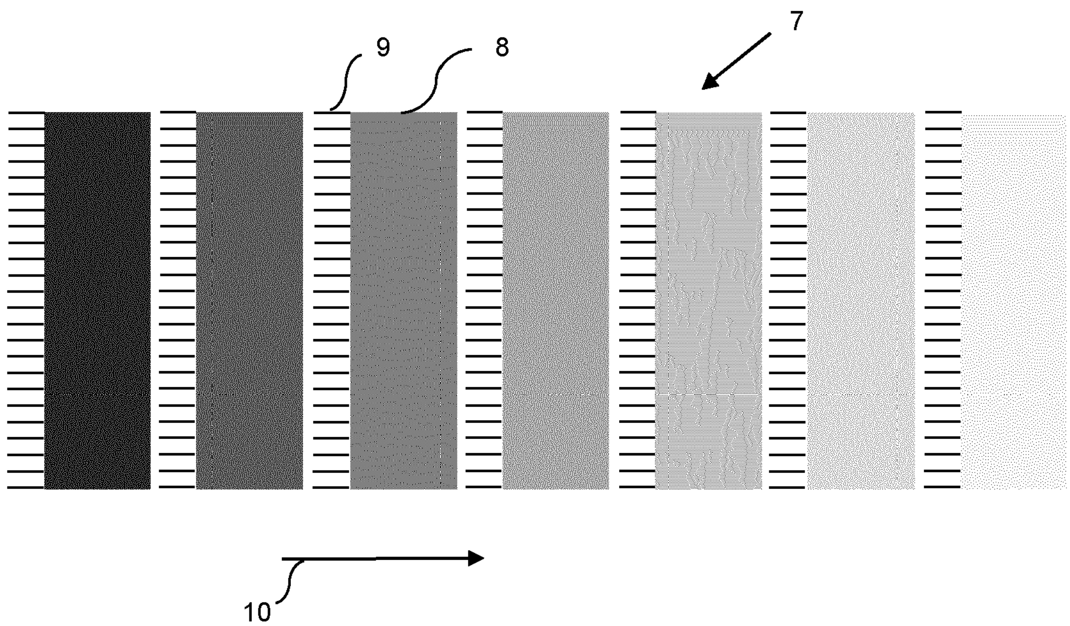

Fig. 2

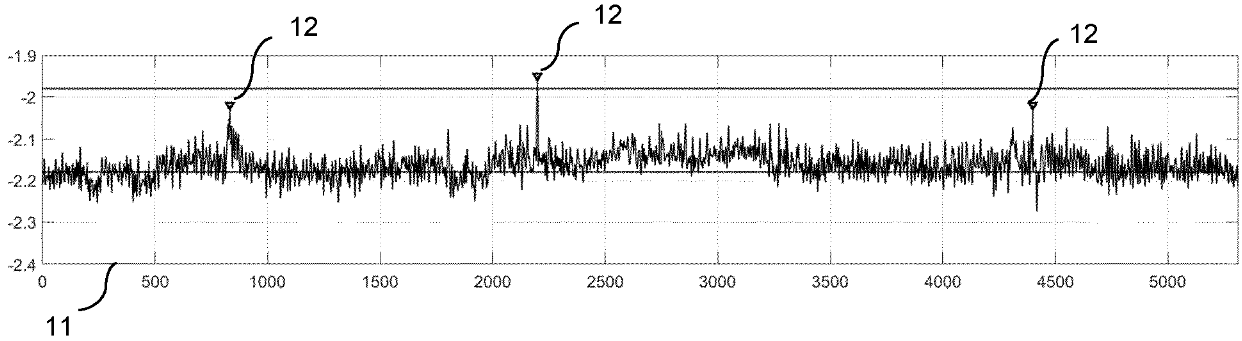
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Fig. 3

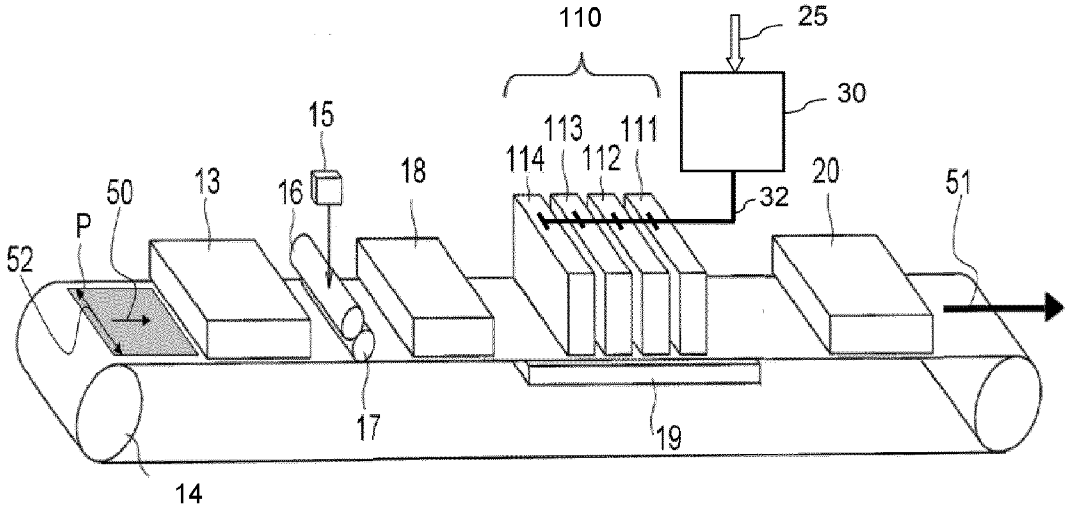
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Fig. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 22 19 2142

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	2 February 2023	Hartmann, Mathias

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

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