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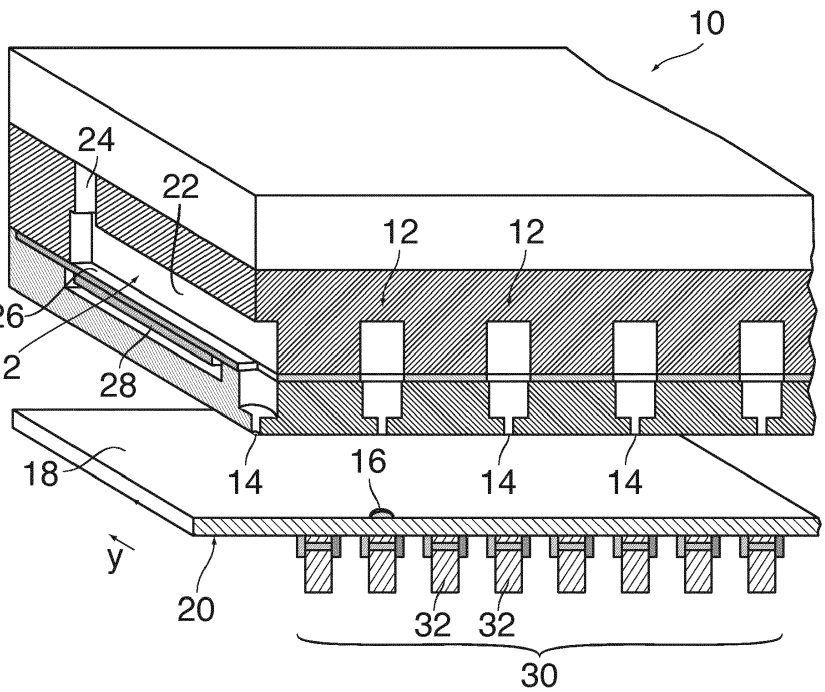
(54) METHOD OF MONITORING A JETTING UNIT

(57) A method of monitoring a jetting unit (12) in a jetting device (10) in which a droplet of a liquid is jetted out onto a receiving medium (20), the method comprising a step of measuring a physical property of the droplet of liquid, characterized in that the physical property is measured at a time and position when and where the droplet settles on a first surface (18) of the receiving medium (20) and forms a dot (16) thereon, the measurement being carried out from a second side of the receiving medium (20) opposite to the side where the dot (16) is formed.

Fig. 1



EP 3 173 239 A1

Description

[0001] The invention relates to a method of monitoring a jetting unit in a jetting device in which a droplet of a liquid is jetted out onto a receiving medium, the method comprising a step of measuring a physical property of the droplet of liquid.

[0002] More particularly, the invention relates to a method of monitoring the state of jetting nozzles in an ink jet print head.

[0003] In an ink jet print head, nozzle failures may occur because the ink tends to dry out in the nozzle when the jetting unit is not used for a certain time, so that the nozzle becomes clogged. It is desirable to be able to detect such nozzle failures so that appropriate counter measures may be taken, which may consist for example in moving the print head to a maintenance station where the nozzles are cleaned.

[0004] When the nozzle failure can be detected in real time, it may even be possible to compensate for the nozzle failure. For example, when it is detected that a nozzle has failed and a gap is left at a corresponding pixel position in the printed image, it may be possible to activate another nozzle of the print head in order to fill the gap or at least in order to camouflage the defect. For example, when the print head scans the receiving medium, e.g. a sheet of paper, in a multi-pass mode, and a nozzle failure is detected in a first pass, it is possible to activate another nozzle of the print head in a second pass at suitable timing for replacing a missing dot on the receiving medium.

[0005] US 7 657 093 B2 discloses a check processing device having an ink jet print head for printing characters onto a check with magnetic ink, and a magnetic ink character reader (MICR) for reading the magnetic information from the check. In this device, although the character reader is capable, in principle, of detecting defects in a printed image and thereby indirectly detecting also nozzle failures, it is not possible to monitor the condition of the jetting units of the ink jet printer in real time because the ink jet printer and the character reader are disposed at different locations in the device.

[0006] US 7 396 102 B2 discloses a method of monitoring an ink jet print head wherein the droplets ejected from the nozzles are electrically charged, and the electric charge of the droplets is measured when the droplet has left the nozzle and passes through an annular electrode before it hits the receiving medium. This method requires, however, that a sufficient space is available between the nozzle and the surface of the receiving medium. On the other hand, a large distance between the nozzles and the surface of the receiving medium compromises the accuracy with which the droplets can be positioned on the receiving medium.

[0007] It is an object of the invention to provide a method of monitoring jetting units, which permits more freedom in the design of the jetting device.

[0008] In the method according to the invention, in order to achieve this object, the physical property is measured at a time and position when and where the droplet settles on a first surface of the receiving medium and forms a dot thereon, the measurement being carried out from a second side of the receiving medium opposite to the side where the dot is formed.

[0009] Thus, since the physical property is measured from the back side of the receiving medium, the space between the nozzle and the first side of the receiving medium can be made as small as desired. Nevertheless, the measurement can be carried out at the very moment when the droplet is jetted out and settles on the receiving medium and forms the dot. Thus, it is possible to monitor the condition of the jetting unit in real time.

[0010] The physical property being measured may be a magnetisation of the dot formed by the liquid. In that case, the liquid to be jetted out may be a magnetic ink similar to or identical with the magnetic inks that are presently being used in MICR. For example, the ink may contain ferromagnetic micro-particles, e.g. particles of magnetite, which may optionally be encapsulated in a resin coating in order to avoid an adverse effect on the colour of the ink.

[0011] More specific optional features of the invention are indicated in the dependent claims.

[0012] A magnetic sensor, e.g. a planar hall effect (PHE) sensor may be disposed at the back side of the receiving medium for detecting the magnetisation of the dot or rather the magnetic particles dispersed therein by detecting a magnetic field that emanates from the dot of cured or curing liquid and penetrates the receiving medium.

[0013] When a magnetisation of the dots is detected, one and the same matrix of magnetic sensors may be used for the monitoring method according to the invention and for conventional MICR applications.

[0014] In case of an ink jet printer, it may be advantageous to provide not just one sensor for monitoring a single jetting unit or nozzle, but rather a sensor array comprising two or more sensors for measuring the physical property with a spatial resolution that is higher than the print resolution of the print head. This offers the possibility to detect a larger variety of defects that result from malfunction states of the jetting units. For example, when parts of the nozzle surface in which the nozzle orifices of the jetting units are formed have become wetted with liquid, this may change the direction in which the droplets are jetted out, resulting in a deviation of the position of the dot on the receiving medium from the target position. If the sensor arrangement is capable of detecting such deviations, it is possible to detect defects of this type even when the nozzle does not fail completely. Similarly, it is possible to detect a so-called beading phenomenon which occurs when there is a mismatch between the cohesion of the liquid and the adhesion between the liquid and the surface of the receiving medium, causing adjacent droplets to coalesce before the liquid is cured or dried out on the surface of the receiving medium.

[0015] The method according to the invention may be carried out while the print head is busy with printing an image. In another embodiment, the method is carried out while the print head is at rest in a home position in the printer. Then, a test procedure may include printing dots onto a test receiving medium and measuring the physical properties of the dots on the test receiving medium. If the test reveals that one or more jetting units of the print head are not functioning properly, a cleaning operation may be initiated before the print head is put to use again.

[0016] A droplet jetting device suitable for carrying out the method according to the invention has been specified in an independent device claim.

[0017] Embodiment examples of the invention will now be described in conjunction with the drawings, wherein:

Fig. 1 is schematic perspective view, partly in section, of a jetting device according to the invention;

Fig. 2 is an enlarged view of sensors for measuring a magnetisation of magnetic ink dots on a receiving medium;

Fig. 3 shows a plan view of a line of ink dots and a sensor arrangement for measuring the magnetisation of the ink dots, along with curves showing the measurement results obtained with different sensors in the arrangement;

Fig. 4 is a graphic representation similar to Fig. 3, but for a different sensor arrangement; and

Fig. 5 is a schematic front view of an ink jet printer arranged for carrying out a method according to the invention.

[0018] As is shown in Fig. 1, a jetting device 10 which forms for example an ink jet print head of an ink jet printer in a combined MICR reader and writer comprises a plurality of jetting units 12 forming a linear array of nozzles 14 for jetting out droplets of liquid ink so as to form ink dots 16 on a first (top) surface 18 of a receiving medium 20.

[0019] Each jetting unit 12 has a pressure chamber 22 to which liquid ink is supplied from a feed line 24 and which is delimited on one side (the bottom side in this example) by a flexible membrane 26. A piezoelectric actuator 28 is attached to the surface of the membrane 26 outside of the pressure chamber 22 so as to cause the membrane 26 to deform in a bending mode when a voltage is applied to the actuator. One end of the pressure chamber 22 is connected to the nozzle 14. When the actuator 28 is energized, the deformation of the membrane 26 creates an acoustic pressure wave in the liquid ink in the pressure chamber 22, and the pressure wave propagates to the nozzle 14, so that an ink droplet is jetted out.

[0020] In this example, the pressure chambers 22 of the jetting units 12 are filled with magnetic ink, i.e. a liquid in which ferromagnetic particles have been dispersed. A sensor arrangement 30 forming a matrix of magnetic sensors 32 is disposed at a second (bottom) side of the receiving medium 20 so as to be opposed to the nozzles 14.

[0021] In the example shown, the sensors 32 are arranged in a row that is aligned with the line of nozzles 14 but with a pitch that is only half the pitch of the nozzles 14, so that only every second sensor 32 is arranged exactly opposite to one of the nozzles 14, whereas the other sensors are disposed half way between the nozzles. Optionally, two or more further rows of sensors 32 may be provided in parallel with the row that has been shown here, so as to form a regular matrix in which the sensors 32 are arranged in a square grid. This permits to measure the magnetisation of the dots 16 of magnetic ink with a spatial resolution that is twice the printing resolution of the print head.

[0022] The design and function of the sensors 32 will now be explained in conjunction with Fig. 2, where two of the sensors 32 have been shown on a larger scale. The sensors 32 are PHE sensors and each have a sensitive layer 34 capable of sensing a magnetic field H that has a component in the plane of the layer 34 which is parallel to the receiving medium 20.

[0023] In the example shown, two permanent magnets 36, 38 are disposed on opposite sides of each sensor 32 and generate a magnetising field H_0. The magnetising field H_0 is approximately a dipole field one lobe of which penetrates the receiving medium 20 and is oriented parallel to the top surface of the receiving medium 20 at the position where an ink dot 16 is to be formed.

[0024] In the left part in Fig. 2, the ink dot 16 has only been shown in phantom lines, indicating that no dot has actually been formed. Consequently, the magnetising field H_0 is not disturbed. However, when a dot 16 is formed, magnetic particles 40 that are dispersed in the ink will be magnetised by the magnetising field H_0, and the ink dot 16 will itself become a magnet. This has been shown in the right part of Fig. 2. Thus, the dot 16 becomes itself the source of a magnetic field H_i which penetrates the receiving medium 20 and is detectable in the sensitive layer 34 of the sensor 32. It will be understood that the magnetic field H_i superposes the magnetising field H_0 and, as shown, is oriented to be opposite to the magnetising field in the sensitive layer 34. As a consequence, the total magnetic field that is detected by the sensor 32 is weakened when the dot 16 is present, and this weakening of the magnetic field is reflected in an electronic sensing signal that is output by the sensor 32.

[0025] In a modified embodiment, the permanent magnets 36 and 38 may be replaced by two pairs of permanent magnets with opposite polarities, so that a magnetising field H_0 would still be generated at the position of the ink dot 16 but the magnetising field would be approximately zero in the sensitive layer 34, which permits a higher sensitivity in the detection of the ink dot 16.

[0026] On the other hand, it is not compulsory that each sensor 32 has its own permanent magnets 36, 38 for generating the magnetising field H_0. Instead, permanent magnets may be arranged to create a substantially homogenous magnetising field H_0 extending over the entire area of the sensor arrangement 30. Optionally, electromagnetic coils may also be provided for generating the magnetising field H_0.

[0027] Fig. 3 shows, in a plan view, another possible arrangement of magnetic sensors 32 along with a row of ink dots 16 which have been printed with the line of nozzles 14. Target positions of the ink dots 16 have been designated by letters a to l.

[0028] In this sensor arrangement, each target position is surrounded by four sensors 32 in the configuration of a square, but two adjacent target positions share a common pair of sensors 32. The two sensors 32 that are located between the target positions a and b shall be labelled as "a1" and "a2". Similarly, the sensors between the target positions b and c shall be labelled as "b1" and "b2", and so on. For clarity reasons, only labels a1 and a2 are indicated in Fig. 3.

[0029] For the sensors in the right column in Fig. 3, i. e. the sensors with the labels a2 - 12, Fig. 3 also shows curves Ha - Hl which represent the measured magnetic field H_i (Fig. 2) as a function of time t. All curves Ha - Hl show a sudden rise at a time t0 which is the time when the ink droplet hits the top surface of the receiving medium 20 and settles there to form the dot 16. Then, the curve reaches a certain peak value and then decays gradually because the receiving medium 20 will be moved relative to the sensors 32. For simplicity, it shall be assumed that, in the examples illustrated in Figs. 1 to 4, the jetting device 10 is a stationary page-wide print head and the receiving medium 20 is moved relative to the stationary sensors 32 along a transport path in the direction y in Fig. 1, 3 and 4.

[0030] In the target positions a and b, the ink dots 16 have hit the receiving medium exactly at the required target positions and the dots have the required size, i.e. the ink droplets had exactly the required volume. Consequently, the curve Ha, as measured with the sensors a1 and a2 between these target positions, reaches a peak value that corresponds to a target value Ht.

[0031] In the target position c, no ink dot has been formed because of a nozzle failure. Consequently, the curves Hb and Hc measured on either side of this target position do not reach the target value Ht but reach only approximately one half of this target value. Thus, by comparing the peak heights of the curves Hb and Hc to the target value, it can be decided that no ink dot has been formed in the target position c, i.e. that a nozzle failure has occurred.

[0032] As for the target position d, an ink dot has been formed at the correct position so that the curve Hd reaches (almost) the target value. However, in the next target position e, a slight aberration of the ink droplet has occurred, so that the dot 16 is shifted somewhat towards the next target position f and, consequently, is at a larger distance from the sensor with the label d2. This is the reason why the curve Hd does not quite reach the target value. In contrast, the curve He exceeds the target value, because the dot 16 is closer to the sensor labelled e2.

[0033] The curve Hf for the next target position f has approximately the normal shape, indicating that the dot has been formed and is in the correct position.

[0034] For the next target position g, an aberration of the dot 16 has occurred, but this time in the direction normal to the row of the nozzles 14 and sensors 32. As a consequence, the dot is closer to the sensor labelled g2, so that the related curve Hg exceeds the target value. In contrast, the curve for the sensor labelled g1 on the other side of the row, which curve has not been shown here, would fall somewhat short of the target value.

[0035] In the target position h, the ink dot has been formed in the correct position, but nevertheless the curve Hh does not quite reach the target value because no proper dot has been formed in the adjacent target position i.

[0036] More precisely, a so-called beading phenomenon has occurred for target positions i - 1. The ink dots that should have been formed in these positions have coalesced, and almost all the liquid ink has been sucked into a large bead 16' and the target position k, whereas only minor filaments are left in the target positions i, j and l. As a consequence, the curves Hi and Hl are clearly below the target value whereas the curves Hj and Hk adjacent to the large bead 16' clearly exceed the target value.

[0037] Thus, by analysing the curves Ha - Hl taken with this sensor arrangement, it is possible to detect not only nozzle failures but also other types of malfunctions such as beading or aberrations of ink dots in any direction. Similarly, it would be detectable when an ink dot is formed at the correct position but does not have the correct volume.

[0038] Fig. 4 illustrates yet another example of a sensor arrangement. In this example, each of the nozzles 14 (Fig. 1) and, consequently, each target position for the ink dots is associated with an internal sensor 32i which has a circular foot print, and an external sensor 32e having an annular foot print and surrounding the internal sensor 32i.

[0039] In the target position a, (the labelling of the target positions is the same as in Fig. 3), the ink dot 16 has been formed exactly at the correct position and in the correct size. Consequently, a curve Hai representing the magnetic field measured with the internal sensor 32i (the second letter "a" being the label of the target position) has a peak value corresponding to a first target value Hti. Similarly, a curve Hae for the external sensor 32e has a peak value corresponding to a (lower) second target value Hte.

[0040] As for target position c, the ink dot is missing due to nozzle failure, and the corresponding curve Hci is flat, and the curve Hce is almost flat (except for minor influences from the neighbouring ink dot in target position d).

[0041] In target position d, the ink dot 16 has the same aberration as in Fig. 3, and the curve Hdi for the internal sensor is slightly below the target value Hti. On the other hand, since the dot 16 now overlaps with the annular foot print of the external sensor 32e, the corresponding curve Hde is above the target value Hte.

[0042] Curves Hgi and Hge with the same shapes are found also for the target position g because this sensor arrangement is not sensitive to the direction of the aberration. In the target position i, the beading has resulted in curves Hii and Hie below their target values, whereas curves Hki and Hke for the target position k (centre of the bead 16') exceed their target values.

[0043] Fig. 5 shows an example of a jetting device 42 configured as an ink jet printer wherein a print head 44 (having the jetting units 12 and the nozzles 14 in the bottom face) is mounted on a carriage 46 that is arranged to move along guide rails 48 across a transport path 50 for recording media 52. The transport path 50 is constituted for example by an endless conveyer belt 54 that is passed around conveyer rollers 56 and moves over a platen 58 disposed underneath a portion of the guide rails 48 that constitutes a printing zone 60.

[0044] A cleaning station 62 for cleaning the print head 44 is formed at an opposite end of the guide rails 48. The cleaning station 62 comprises a cleaning device 64 for cleaning a nozzle face of the print head 44 as well as a collecting tank 66 arranged to collect cleaning liquid and/or ink that is jetted out from the nozzles of the print head 14 in order to scavenge the nozzles.

[0045] A portion of the guide rails 48 intervening between the printing zone 60 and the cleaning station 62 constitutes a test zone 68 where the jetting units of the print head may be tested. In the test zone 68, another transport path 70 is formed by a number of conveyer rollers 72 arranged to advance a receiving medium 74 over a stationary magnetic sensor arrangement 76 of any of the types that have been described in conjunction with Figs. 1 to 4.

[0046] In Fig. 5, the carriage 46 is shown in a home position within the test zone 68. The receiving medium 74 is a test receiving medium on which a test pattern can be printed by appropriately actuating the print head 44 in the home position. The distance between the nozzle face of the print head 44 and the receiving medium 74 at the test station is the same as the distance between the print head and the recording sheet 52 in the printing zone. Thus, the jetting behaviour of the print head can be tested under realistic conditions, and the sensor arrangement 76 is capable of capturing the test pattern and of identifying any possible nozzle failures in the same way as has been described in conjunction with Figs. 3 and 4.

[0047] A test may be performed whenever the print head 44 is in the home position, and when no inacceptable nozzle failures are detected, the printer is ready for printing. On the other hand, when substantial nozzle failures are detected, the carriage 46 is moved into the cleaning station 62 for cleaning the print head. When the cleaning operation has been completed, the carriage 46 is moved back to the test zone 68 where the result of the cleaning operation may be checked.

[0048] In the example shown, the sensor arrangement 46 extends over the entire width of the print head 44 when the same is held in the test station. Of course, in a modified embodiment, the sensor arrangement 76 may extend only over a narrow portion of the print head 44, and the tests may be performed by moving the carriage 46 so as to move the print head 44 over the sensor arrangement.

Claims

1. A method of monitoring a jetting unit (12) in a jetting device (10; 42) in which a droplet of a liquid is jetted out onto a receiving medium (20; 74), the method comprising a step of measuring a physical property of the droplet of liquid, wherein the physical property is measured at a time and position when and where the droplet settles on a first surface (18) of the receiving medium (20; 74) and forms a dot (16) thereon, the measurement being carried out from a second side of the receiving medium (20; 74) opposite to the side where the dot (16) is formed and wherein the liquid being jetted out is a magnetic liquid, and the physical property being measured is a magnetisation of the dot (16) on the receiving medium (20; 74).

2. The method according to claim 1 , wherein a change in the physical property is measured at a time (t0) when the dot (16) is being formed on the first surface (18) of the receiving medium (20; 74).

3. The method according to claim 2, wherein a failure of a jetting unit (12) is detected when the jetting unit has been activated and no change in the physical property is measured within a certain time interval after the jetting unit has been activated.

4. The method according to any of the preceding claims, wherein a spatial distribution of the physical property of dots (16) on the receiving medium (20; 64) is measured relative to positions of a plurality of jetting units (12) with which the dots (16) have been formed.

5. The method according to any of the preceding claims, wherein the receiving medium (20; 74) is moved relatively to a stationary sensor arrangement (30; 76) with which the physical property of the dot (16) is measured.

6. A jetting device (10; 42) comprising:

- a jetting unit (12) for jetting out a droplet of a magnetic liquid onto a first side (18) of a receiving medium (20; 74);
- a transport path (70) for the receiving medium (74); and
- a sensor arrangement (30; 76) for measuring a physical property of a dot (16) formed by said droplet of liquid when the droplet has settled on the receiving medium (20; 74), the physical property being a magnetisation of the dot (16) on the receiving medium (20; 74),

wherein the sensor arrangement (30; 76) is disposed at the transport path (70) at a position opposite to the jetting unit (12) and on a side of the transport path facing away from the jetting unit.

7. The jetting device according to claim 6, comprising a plurality of jetting units (12), wherein the sensor arrangement (30) comprises a plurality of sensors (32) for measuring the physical property of a plurality of dots (16) formed by the jetting units (12).

8. The jetting device according to claim 7, wherein the jetting units (12) constitute a print head (44) arranged to print an image onto the receiving medium (20; 74) with a certain printing resolution, and the sensors (32) are arranged to measure the physical property with a spatial resolution that is higher than the printing resolution.

9. The jetting device according to any of the claims 6 to 8, wherein the jetting units (12) and the sensor arrangement (30) are held stationary relative to one another.

10. The jetting device according to any of the claims 6 to 8, wherein the jetting units (12) are mounted on the carriage (46) that is movable relative to the sensor arrangement (76).

11. The jetting device according to any of the claims 6 to 10, wherein the sensor arrangement comprises a Hall Effect sensor.

Fig. 1

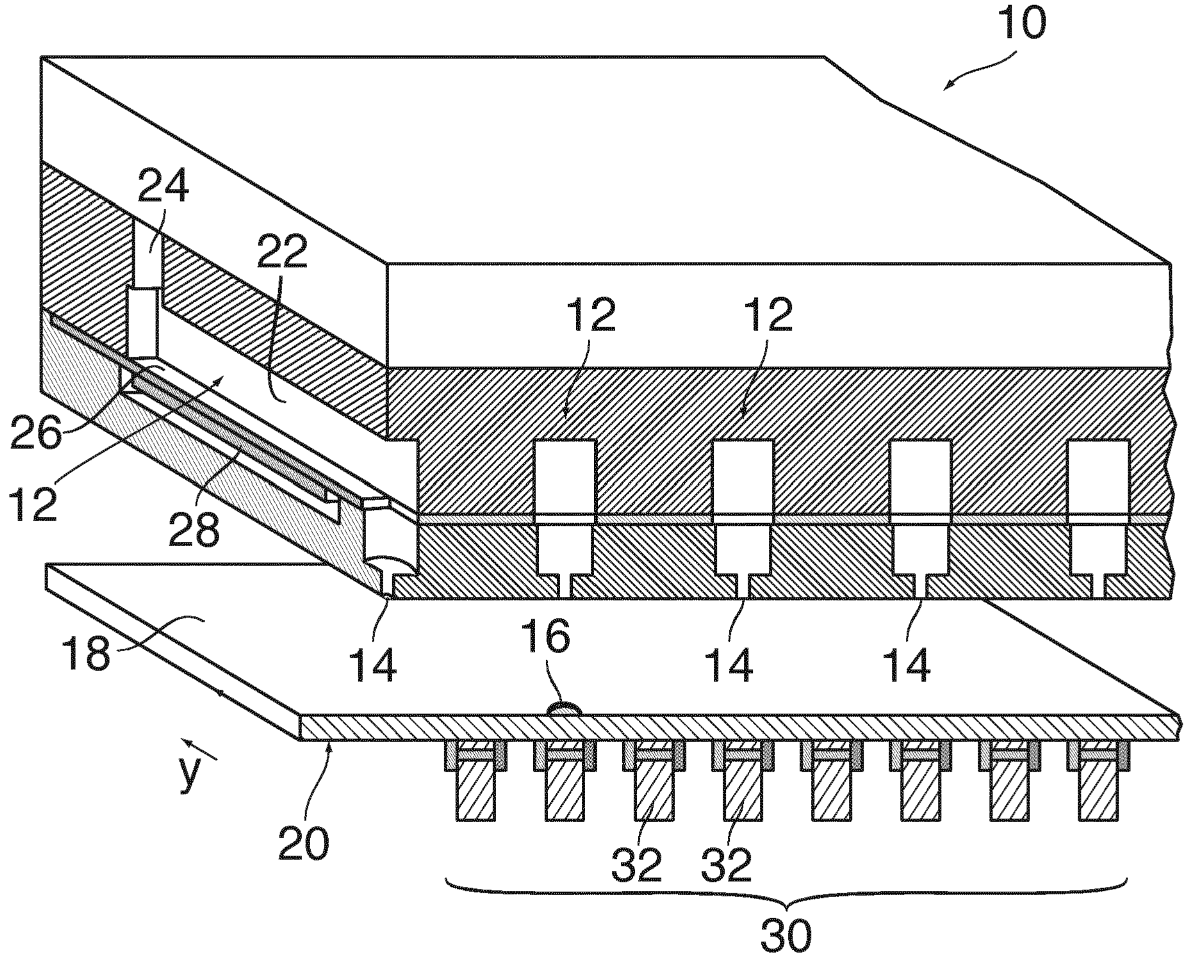

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Fig. 2

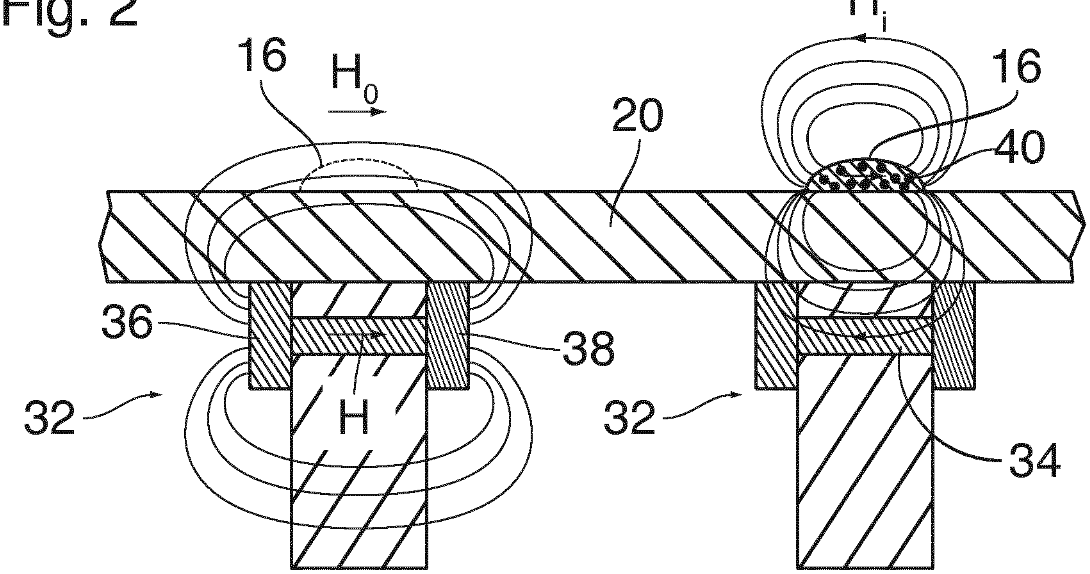
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Fig. 3

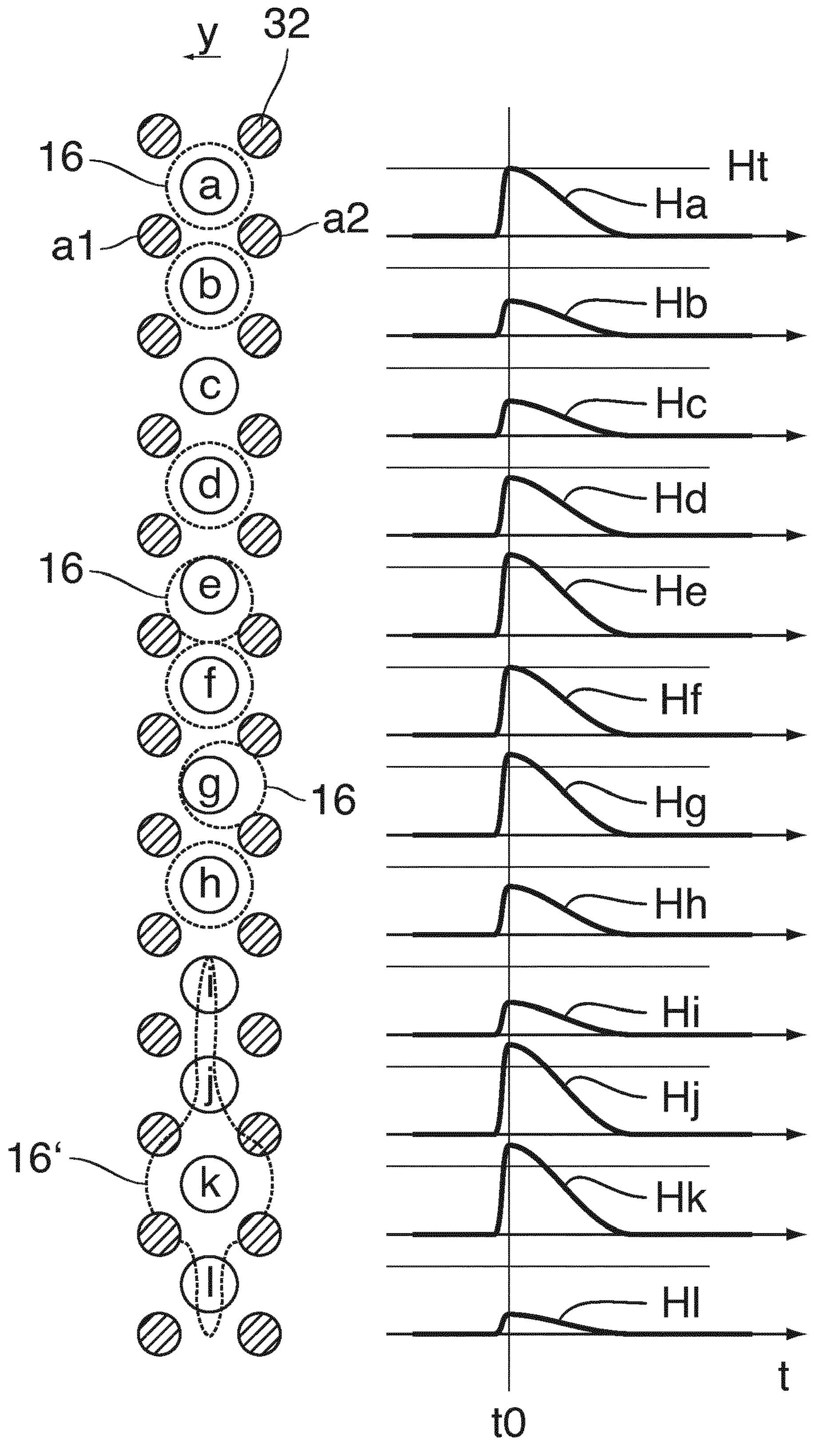
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Fig. 4

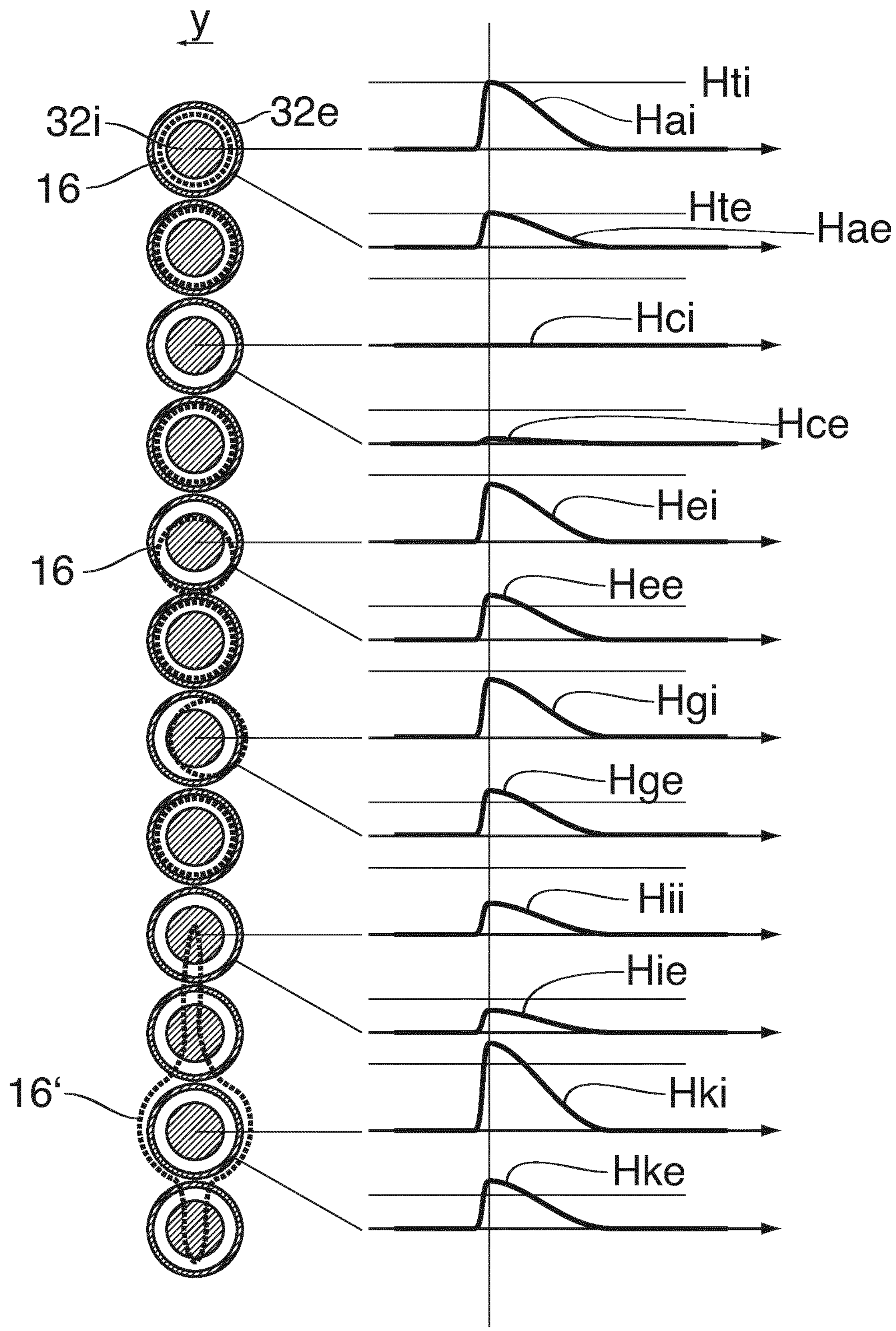
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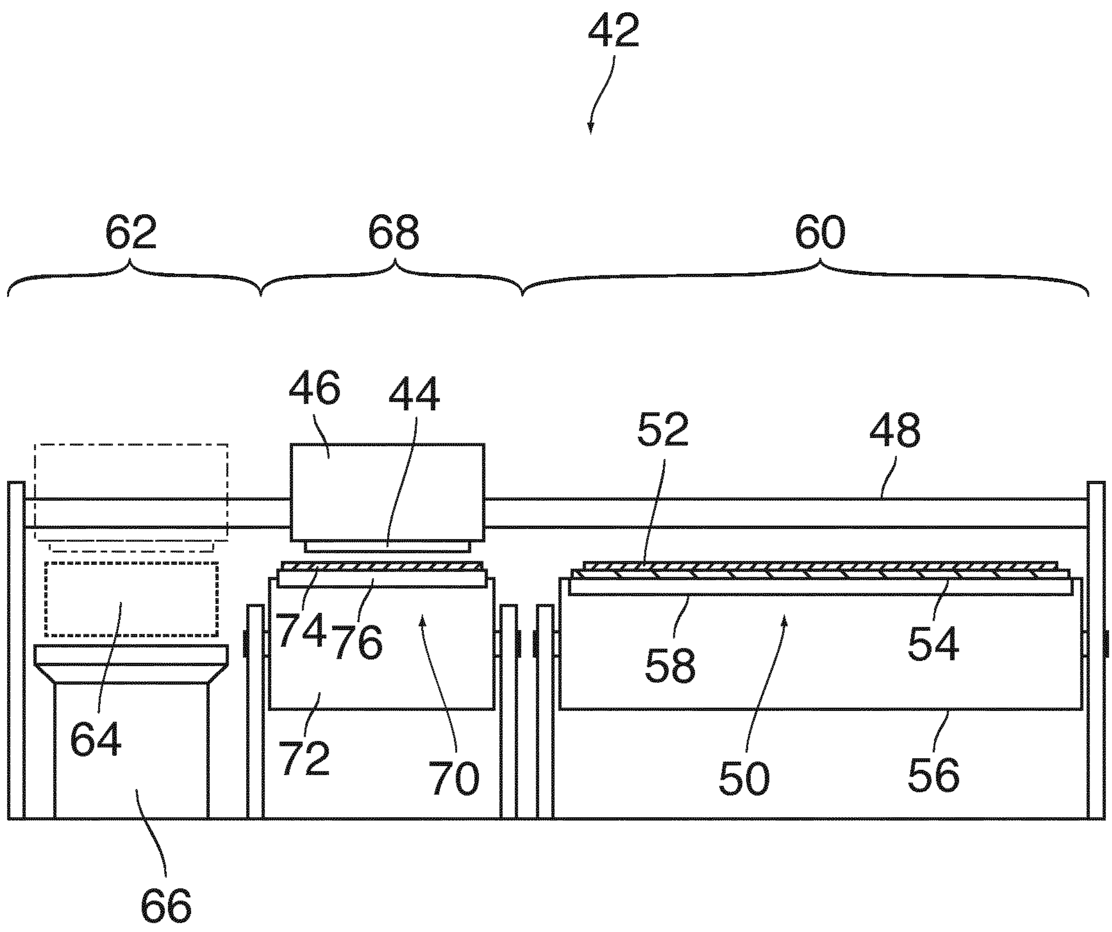
Fig. 5



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EUROPEAN SEARCH REPORT

Application Number
EP 16 20 0094

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			TECHNICAL FIELDS SEARCHED (IPC)
			B41J

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	20 March 2017	João, César

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