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(54) **METHOD FOR DETECTING DEFECTS IN THE NEEDLES OF AN AUTOMATIC KNITTING MACHINE, AND CORRESPONDING SYSTEM AND COMPUTER PROGRAM**

(57) Method, system and computer program for detecting defects in the needles of an automatic knitting machine (1), wherein: a digital camera (4) captures digital image frames (5) of a group (6) of working needles (3); an automatic image recognition is carried out to determine a first pattern jointly defined by the needles (3) and/or a second pattern defined by a length of yarn (7) interacting with the needles (3); at least one parameter is automatically derived from the first or second pattern; a deviation of said parameter from a predetermined reference is automatically calculated; and in function of said deviation, the presence of a defect in the group (6) of needles (3) is automatically determined.

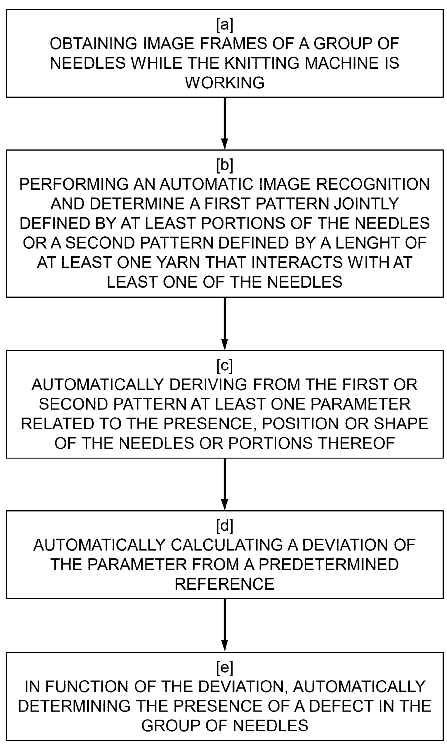

FIG. 20

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Description

Field of the invention

[0001] The invention is comprised in the field of automatic knitting machines.

[0002] The invention more specifically relates to a method for detecting defects in the needles of an automatic knitting machine, said automatic knitting machine being of the type comprising a plurality of yarn feeders, a plurality of movable needles, each of said needles being adapted to subsequently catch and free a yarn provided by one of said yarn feeders when said needle is moved, and an actuating device for automatically moving said needles according to a preestablished pattern for manufacturing a knitted fabric from the yarns provided by said yarn feeders.

[0003] The invention also relates to a system for detecting defects in the needles of an automatic knitting machine of this type, and a corresponding computer program to carry out the method.

Prior art

[0004] Automatic knitting machines are commonly used for manufacturing knitted fabrics at industrial scale. These machines are designed to work intensively. They have a high number of components, including a high number of needles and the mechanics to move them, which must work in a very precise manner to knit each stitch without defects. The machine is usually equipped with sensors and monitored by a human knitter who can stop the process if something goes wrong. Both the machine components and the produced knitted fabric can be monitored. When the machine is stopped because a defect has been detected in the knitted fabric, there is a high cost associated to the interruption because the human knitter must check the knitted fabric, discard the section with defects, fix the problem and restart the machine. Therefore, it is of great importance to early detect the signs of defects in machine components which can cause defects in the fabric.

[0005] Defects in the needles are one of the main causes of defects in the fabric. The needles are continuously moved in reciprocating movement and, to form the stitch, they come into contact with the yarn that is under tension. This interaction of the needles with the yarn progressively causes wear and misalignment of the needles that can cause defects in the fabric. A needle break can also occur due to interaction with the yarn or with the mechanisms that move the needles.

[0006] US6035669A discloses a method for detecting broken hooks of needles in a knitting machine. Each needle is slidably received in a cam system in which a recess segment is formed, so that butts of needles having broken hooks are urged into the recess segment but butts of intact needles are biased and do not enter the recess segment. A sensor in the recess segment identifies butts of broken needles.

[0007] CN103437061A discloses a method for detecting defects in the needles of a knitting machine. The moving needles successively pass in front of the end of an optical fiber emitting a LED light. The light reflected on the surface of the needle is conducted by an optical fiber to a photodetector which produces a pulse signal. A change in the shape or the relative position of a needle causes an alteration in the frequency of the pulse signal, which is detected and interpreted as a defect in a needle.

[0008] CN109881356A discloses a method for detecting defects in the needles of a knitting machine with a digital camera. An image frame of a group of needles is taken by the digital camera and processed so that an image of each individual needle is cropped, and the shape thereof is compared to predetermined shapes of a normal needle, a broken needle and a bended needle.

[0009] WO2020079493A1 discloses a circular knitting machine in which a digital camera is fixed to the rotating cylinder for continuously monitoring the knitted fabric produced by the machine. The digital camera takes digital images of the knitted fabric which is continuously produced by the machine, and which rotates together with the rotating cylinder, on a section of said knitted fabric that has been flattened before being rolled in a cylinder under the machine, and which is illuminated by a lighting. The digital images are processed to automatically recognise defective patterns or non-uniformities in the knitted fabric. The automatic recognition is performed by computing Gaussian filters, Local Binary Pattern (LBP) algorithms or machine learning techniques, that are tuned in function of the type of fabric which is being produced (Jersey, Interlock, etc.).

Description of the invention

[0010] The purpose of this invention is to provide a method for detecting defects in the needles of an automatic knitting machine of the type indicated above in the chapter "Field of the invention", which can be easily implemented at low cost without modifying the knitting machine and allowing an automatic and reliable detection of different sort of defects in the needles.

[0011] This is achieved by means of a method for detecting defects in the needles of an automatic knitting machine of this type, characterized in that a digital camera is arranged to capture digital image frames of a group of needles while the automatic knitting machine is working manufacturing the knitted fabric, the needles being adjacent to each other in said group;
and in that the method comprises the following steps:

[a] obtaining from said digital camera image frames containing at least portions of the needles of said group while said automatic knitting machine is working manufacturing said knitted fabric;

[b] performing an automatic image recognition in said image frame to determine at least one between a

first pattern jointly defined by at least portions of the needles of said group and a second pattern defined by a length of at least one yarn that interacts with at least one of the needles of said group;

[c] automatically deriving from said first or second pattern at least one parameter related to the presence, the position or the shape of said needles or portions of said needles in said group;

[d] automatically calculating a deviation of said at least one parameter from a predetermined reference;

[e] in function of said deviation, automatically determining the presence of a defect in said group of needles.

[0012] The term "needle" used in the present document refers to a needle as a whole, including all its parts. For instance, when the needle is a latch needle, the term "needle" refers to the needle including the latch.

[0013] As will be seen below in the detailed description of the embodiments, the method according to the invention can be easily implemented by simply installing a digital camera and using a software to carry out an automatic image recognition and determination of a defect in a needle.

[0014] Installing a camera in a position for capturing proper digital image frames of the group of needles while the automatic knitting machine is working is generally not a problem. The camera can be attached to the knitting machine or an external frame.

[0015] It must be noted that the method according to the invention is not based on the recognition of the shape of an individual needle, but on recognising a first pattern which is jointly defined by al least portions of the needles of the group, and/or a second pattern defined by a length of at least one yarn that interacts with at least one of the needles of said group, contained in an image frame taken by the digital camera. This provides a faster a more robust process since there is no need to analyse the needles individually or knowing the exact shape of a needle. In addition, the method allows a more reliable detection of a defect in the needles because the pattern can be simple, and the deviation easily determined. In addition, the method can be easily adapted to a variety of knitting machines, equipped with different types of needles like for instance latch needles, compound needles and patent needles, without disassembling any part. Adapting the method to a particular machine can be done by software, by initially selecting the pattern and the parameter from an image frame delivered by the digital camera while the machine is working and when all the needles are known to be without defects, and by setting a predetermined reference for said parameter from said image frame. An important aspect of the invention is that it allows detecting not only defects in the needles that cause a faulty stitch in the fabric that is being manufactured by the knitting machine, but also defects in the needles before they cause such faulty stitch in the fabric. For instance, a slight deviation in the hook or the latch of a needle, or an initial wear in some parts of the needle due to friction with the yarn, are defects that do not initially cause a faulty stitch, but which can be detected by the method according to the invention before they become critical and they cause a defect in the yarn. The invention thus makes it possible to carry out preventive maintenance in an efficient manner by replacing the needles that are identified as being likely to cause defects in the yarn. The invention also allows determining a degree of severity of a defect and issuing a corresponding warning signal. A first type of warning signal indicates that the knitting machine must be stopped immediately because a critical defect has been detected in one of the needles, which should be causing a faulty stitch. Another type of warning signal indicates that the knitting machine should be stopped as soon as possible, and a needle should be inspected and eventually replaced, because a slight defect has been detected in the needle, that can cause soon a faulty stitch.

[0016] In preferred embodiments, the first pattern determined in step [b] comprises a plurality of spots in the image frame, each of said spots corresponding to a reflexion of light in a portion of a needle of the group. This provides a particularly fast and easy way for determining the first pattern and also for determining the parameter, the predetermined reference and the deviation, since a set of spots is easily recognizable by software. This solution is particularly suitable for the needles of a knitting machine, because said needles are usually metallic, with a surface that reflects light well, and have various curved parts that can generate a spot of reflected light in the image frame. In addition, the method according to this solution can be easily transferred from one knitting machine to another with just a few adjustments, because even if the shape of the needles is not the same, the first pattern of a group of spots created by equivalent parts of the needles can be very similar. Another advantage of this solution is that it makes it easier to identify which needle has a defect.

[0017] The term "spot" used in the present document must be interpreted according to its usual meaning: a small area visibly different, as in color or finish, from the surrounding area. The spot may have any shape: it is not necessarily a circular dot.

[0018] Preferably, the parameter automatically derived from said first pattern in step [c] comprises at least one of the group consisting of the number of spots in the first pattern, the shape of the spots, the area of the spots, the position of the spots in the image frame and a relative distance between two of said spots. This allows to determine in a simple and effective manner a significant deviation in the parameter and therefore a defect in one of the needles. For instance, when the parameter is the number of spots in the first pattern, missing one of these spots is easily recognisable and is a clear indication of a defect in the corresponding needle.

[0019] Preferably, each of the spots corresponds to a reflexion of light in a curved surface of a portion of each of the needles. These spots are particularly well defined and separated from each other.

[0020] Preferably, the portion of the needle with a curved surface, in which a reflexion of light occurs which corresponds to the spot, is chosen to be a hook adapted to subsequently catch and free a yarn when said needle is moved. The hook is one of the portions of the needle that suffers the most wear due to friction with the yarn, and in which a defect is more likely to appear with use. An excessive wear on the hook alters the shape, position or existence of the spot and therefore it is easily detected.

[0021] Preferably, the portion of the needle with a curved surface, in which a reflexion of light occurs which corresponds to the spot, is chosen to be at a free end of the needle. This is the portion of the needle which usually forms a hook, and which is more accessible for capturing an image with the digital camera when the knitting machine is working. In addition, when the defect is a tilt or a bending of the needle, the free end is the portion of the needle that varies its position at the most, causing a significant change in the shape, position or existence of the corresponding spot will allows to better detect this defect.

[0022] In some preferred embodiments, the needles are latch needles, and said portion of the needle with a curved surface, in which a reflexion of light occurs which corresponds to said spot, is preferably chosen to be a portion of a latch of the needle. Directly detecting a defect in the latch of a needle makes the method more robust. A faulty latch is a quite frequent defect, which can cause the needle not to catch the yarn.

[0023] In preferred embodiments, the second pattern determined in step [b] comprises a line corresponding to a reflexion of light in said length of yarn, said line having one or several discontinuities, each of said discontinuities corresponding to a section of said yarn which passes through a hook of a needle of said group. Similarly as for the spots in the first pattern, the line in the second pattern provides a particularly fast and easy way for determining said second pattern and also for determining the parameter, the predetermined reference and the deviation, since a line with one or several discontinuities is easily recognizable by software. This solution is also particularly suitable for the needles of a knitting machine, because the yarn usually reflects light well and is clearly defining a recognizable line. As for the spots if the first pattern, the method according to this solution can be easily transferred from one knitting machine to another with only a few adjustments, because even if the distribution of the needles is not the same, the second pattern can be very similar. A particular advantage of this solution is that it is very reliable to identify a defect in a needle which causes the yarn to do not pass through the hook of the needle. For instance, in latch needles usually used in automatic knitting machines, this type of defect is usually caused by a broken or deteriorated latch which is unable to close a loop with the hooked end of the needle.

[0024] Preferably, in step [b] both the first pattern and the second pattern are determined by the automatic image recognition, and in step [c] at least a first parameter is automatically derived for the first pattern and at least a second parameter, different from said first pattern, is automatically derived for the second pattern. This provides a very reliable detection of defects in the needles, since a unique defect, for instance a broken needle, can cause a deviation in both first and second parameters.

[0025] Preferably, the parameter automatically derived from the second pattern in step [c] comprises at least one of the group consisting of the number of discontinuities in the line, the length of said discontinuities and the position of said discontinuities in said image frame. This allows to determine in a simple and effective manner a significant deviation in the parameter and therefore a defect in one of the needles. For instance, when the parameter is the number of the discontinuities in the line, missing one of these discontinuities is easily recognisable and is a clear indication of a defect in the corresponding needle.

[0026] Preferably, before step [b], the image frames (6) obtained in step [a] are transformed to monochrome images, therefore making the process of automatic recognition faster. This is an important advantage, since it solves the problem of how the complete quickly enough the process of recognizing the first or second pattern in the portions of needles contained in an image frame, before the next image frame is generated. Transforming the images to monochrome ones implies losing an important part of the information contained in said images, but this does not deteriorate the robustness of the method because it is not necessary to know the exact shape of the spots.

[0027] Preferably, a controlled lighting is focused on said group of needles, so that the light reflexion that creates the spots does not depend on the ambient light present in the place where the machine is located.

[0028] Preferably, the number of needles, of which at least a portion is contained in the image frames, is comprised between 2 and 50, preferably between 2 and 30, more preferably between 5 and 15. These ranges are optimum for determining the pattern, the first or second parameter and the predetermined reference.

[0029] Preferably, when in step [e] the presence of a defect is automatically detected in the group of needles, a needle in which said defect is present is automatically identified in function of the parameter that has been automatically derived in step [c]. This allows to fix the problem by directly replacing the defective needle. It also allows to deduce which portion of the knitted fabric is likely to have a defect due to the defective needle, so that the knitted fabric can be inspected in a more effective manner.

[0030] Although the method according to the invention can be applied to a variety of automatic knitting machines, in preferred embodiments the automatic knitting machine is a circular knitting machine in which said needles are arranged in a rotating cylinder which make said needles to travel along a circumference which is coaxial with said rotating cylinder, and wherein said digital camera is statically arranged, so that it does not rotate with said rotating cylinder, and the digital image frames include a portion of said circumference. The digital camera is statically arranged, so that it does not rotate with said cylinder of needles, and the digital image frames include a portion of said circumference. In these applications, the method according to the invention is particularly advantageous. It is easy to install the digital camera and it is also easy to obtain a stationary pattern in the image frames. The digital camera can be installed on the inner side of the rotating cylinder of needles or on the outer side thereof, depending on the structure of the automatic knitting machine.

[0031] The invention also comprises a corresponding system for detecting defects in the needles of an automatic knitting machine, comprising an automatic knitting machine with a plurality of yarn feeders, a plurality of movable needles, each of said needles being adapted to subsequently catch and free a yarn provided by one of said yarn feeders when said needle is moved, and an actuating device for automatically moving said needles according to a preestablished pattern for manufacturing a knitted fabric from the yarns provided by said yarn feeders;
characterized in that it further comprises:

- a digital camera arranged to capture digital image frames of a group of said needles while said automatic knitting machine is working manufacturing said knitted fabric, the needles being adjacent to each other in said group;
- a processor connected to said digital camera;
- a computer program comprising instructions which, when executed by said processor, cause said processor to carry out the following steps:

  [a] obtaining from said digital camera image frames containing at least portions of the needles of said group while said automatic knitting machine is working manufacturing said knitted fabric;
  [b] performing an automatic image recognition in said image frame to determine at least one between a first pattern jointly defined by at least portions of the needles of said group and a second pattern defined by a length of yarn that interacts with at least one of the needles of said group;
  [c] automatically deriving from said first or second pattern at least one parameter related to the presence, the position or the shape of said needles or portions of said needles in said group;
  [d] automatically calculating a deviation of said at least one parameter from a predetermined reference;
  [e] in function of said deviation, automatically determining the presence of a defect in said group of needles.

[0032] The system optionally has the structural features according to the preferred embodiments discussed above for the method, and the computer program optionally comprises instructions to carry out the steps of the method according to said preferred embodiments.

[0033] The invention also comprises the computer program defined above in the description of the system.

[0034] The invention also comprises other features concerning details illustrated in the detailed description of embodiments of the invention and in the attached drawings.

<u>Brief description of the drawings</u>

[0035] The advantages and features of the invention can be seen from the following description in which, with a non-limiting character with respect to the scope of the main claim, preferred embodiments are described in reference to the drawings.

Fig. 1 is a schematic view of a first embodiment of a system according to the invention. The automatic knitting machine is circular, of the kind with one set of vertical needles and one set of sinkers.

Fig. 2 is a schematic view of a group of working needles in the automatic knitting machine.

Fig. 3 is a view of the upper part of a needle, with the latch in open position.

Fig. 4 is a view of the same upper part of the needle, with the latch in closed position.

Fig. 5 is a more detailed view of a group of working needles in the automatic knitting machine, of which the digital camera obtains image frames. All the needles are without defects.

Fig. 6 is a schematic view of a processed image frame corresponding to Fig. 5, which shows the spots and the line that are used to determine the patterns and the presence of defects in the needles.

Fig. 7 is a view equivalent to Fig. 5, but with one of the needles broken.

Fig. 8 is a schematic view of a processed image frame equivalent to Fig. 6, but corresponding to the situation shown in Fig. 7 with one of needles broken.

Fig. 9 is a view equivalent to Fig. 5, but with the latch of one of the needles broken.

Fig. 10 is a schematic view of a processed image frame equivalent to Fig. 6, but corresponding to the situation shown in Fig. 9 with the latch of one of the needles broken.

Fig. 11 is an image frame of the group of needles of Fig. 5 obtained by the digital camera.

Fig. 12 is a processed monochrome image frame corresponding to the image frame of Fig. 11, in which all the needles are without defects. It is equivalent to the schematic view of Fig. 6.

Fig. 13 is an enlarged portion of the image frame of Fig. 12 which is processed by the software to detect defects.

Fig. 14 is a processed monochrome image frame corresponding to the image frame of Fig. 11, in which one of the needles is broken. It is equivalent to the schematic view of Fig. 8.

Fig. 15 refers to a second embodiment of the system according to the invention. The automatic knitting machine is a circular dial and cylinder weft knitting machine, of the kind with one set of vertical needles and one set of horizontal needles. The figure is a detailed view of a group of working needles, of which the digital camera obtains image frames. All the needles are without defects.

Fig. 16 is a processed monochrome image frame from an image frame of the group of needles of Fig. 15 obtained by the digital camera.

Fig. 17 is equivalent to Fig. 15. It shows an indication of the two rectangular areas which are cropped to form an image frame which is processed by the software to detect defects.

Fig. 18 is an enlarged view of the upper rectangular area indicated in Fig. 17. It is an enlarged portion of the image frame of Fig. 15 which is processed by the software to detect defects in the set of horizontal needles.

Fig. 19 is an enlarged view of the lower rectangular area indicated in Fig. 17. It is an enlarged portion of the image frame of Fig. 15 which is processed by the software to detect defects in the set of vertical needles.

Fig. 20 is a block diagram of the main steps of the method according to the invention.

Detailed description of embodiments of the invention

[0036] Figs. 1-14 refer to a first embodiment of a system and a method according to the invention. In this first embodiment, the automatic knitting machine 1 is a circular knitting machine of the type having a set of vertical needles 3 and a set of sinkers 16 for manufacturing a single jersey knit tubular fabric 17.

[0037] Fig. 1 is a schematic view of the system, in which the knitting machine 1 is represented in a schematic sectional view. The system comprises the automatic knitting machine 1, a digital camera 4, a controlled lighting 13 and a computer system including a processor 15 which is connected to the digital camera 4. A software, including an automatic image recognition algorithm, is executed by the processor 15.

[0038] The automatic knitting machine 1 comprises a plurality of yarn feeders 2, a plurality of movable needles 3, each of said needles 3 being adapted to subsequently catch and free a yarn 7 provided by one of the yarn feeders 2 when the needle 3 is moved, and an actuating device for automatically moving the needles 3 according to a preestablished pattern for manufacturing a knitted fabric from the yarns 7 provided by the yarn feeders 2.

[0039] More concretely, the automatic kitting machine 1 used in the tests described below for Figs. 1 to 14 is a single jersey circular knitting machine, model of CANMARTEX-JUMBERCA brand, with 1728 needles, diameter of 30 inches, and an 18 gauge (number of needles per inch). The needles 3 are arranged in a rotating cylinder 14, so that they travel along a circumference which is coaxial with the rotating cylinder 14. The needles 3 interact with cams which are statically arranged in a dial around the rotating cylinder 14, and which make each needle 3 to move vertically up and down forming stitches while the cylinder 14 rotates continuously. The rotating cylinder 14, actuated by a motor, and the static cams are the actuating device referred to above for automatically moving the needles 3. Since the cams are static, each needle 3 travelling along the circumference has a unique position at each point of said circumference. The sinkers 16 are arranged between the needles 3 and move horizontally to control the movement of the fabric as the machine knits. Fig. 2 is a schematic view of a group of working needles 3 in the automatic knitting machine 1. The needles 3 are all identical. They are latch needles as schematically shown in Figs. 3 and 4. Each needle 3 has a free top end forming a hook 9 and a pivoting latch 10 which is pushed by the yarn of the knit loop as the needle 3 moves up and down, so that the latch 10 subsequently closes and open the hook 9. The hook 9 is adapted to subsequently catch and free a yarn when the needle 3 is moved. Figs. 3 and 4 respectively show the needle 3 with the latch 10 in an open and a closed position. The operation of this type of circular knitting machine with needles and sinkers, as well as the movements of the latch needles to form the knit loops, are not described in greater detail here since they are well known to those skilled in the art.

[0040] The digital camera 4 is statically arranged, so that it does not rotate with the rotating cylinder 14. It is arranged to capture digital image frames 5 of a portion of the circumference along which the needles 3 travel, while the automatic knitting machine 1 is working manufacturing the knitted fabric 17. Image frames 5 captured by the digital camera 4 include a group 6 of needles 3 adjacent to each other. The lighting 13 is a lamp statically arranged so that the light it emits focuses on the group 6 of needles 3. The relative position of the lamp with respect to the digital camera 4 and the intensity of the light emitted by said lamp are adjusted so that a suitable reflexion of light on the needles 3 and, preferably, also on a length of the yarn 7 is obtained, allowing to identify patterns in processed image frames 5 as will be discussed below. In the exemplary embodiment depicted in the figures, the digital camera 4 and the lighting 13 are fixed to a static support, on an outer side with respect to a virtual cylinder that axially extends the rotating cylinder 14. In other embodiments, the digital camera 4 and/or the lighting 13 can be arranged in different positions. For instance, they can be fixed to a static support on an inner side with respect to said virtual cylinder.

[0041] The digital camera 4 used in the tests described below is a video digital camera model TIS-DMK-33UX264 commercialized by the German firm The Imaging Source Europe GmbH. It is equipped with a Sony IMX264 sensor and has a 2448x2048 pixels resolution and a 35 PFS (frames per second) (FPS) video capture. The sensor operates with a Global Shutter CMOS image capture method, allowing to collect all the data at the same time without a lag due to the shutter. Fig. 11 shows a primary, non-processed image frame 5 of the group 6 of needles 3 captured by the digital camera 4.

[0042] The method according to the invention comprises the following main steps:

[a] obtaining from the digital camera 4 image frames 5 containing at least portions of the needles 3 of the group 6 of needles 3 while the automatic knitting machine 1 is working manufacturing a knitted fabric;
[b] performing an automatic image recognition in the image frame 5 to determine at least one between a first pattern jointly defined by at least portions of the needles 3 of the group 6 and a second pattern defined by a length of at least one yarn 7 that interacts with at least one of the needles 3 of the group 6;
[c] automatically deriving from said first or second pattern at least one parameter related to the presence, the position or the shape of the needles 3 or portions of said needles 3 in said group 6;
[d] automatically calculating a deviation of said at least one parameter from a predetermined reference;
[e] in function of said deviation, automatically determining the presence of a defect in the group 6 of needles 3.

[0043] Figs. 5 to 10 are schematic, idealized figures of image frames during these steps.

[0044] Figs. 5 and 6 respectively show a non-processed image frame 5 of a group 6 of working needles 3 in the automatic knitting machine 1, taken by the digital camera 4 in step [a], and a corresponding processed image frame 5 used in the subsequent steps of the method. The image frames 5 contain 10 needles 3 in total, although only eight of them form the first pattern as will be discussed below. In the figures only some needles are indicated with their numerical refence 3 for the sake of clarity. All the needles are known to be without defects. Before step [b], the image frame 5 of Fig. 5 obtained in step [a] is processed: it is oversaturated and transformed to monochrome. This processed image frame 5 is schematically shown in Fig. 6.

[0045] In an initial step, in which the automatic knitting machine 1 is working and all the needles 3 are known to be without defects, a processed image 5 like the one schematically shown in Fig. 6 is analysed. From this initial analysis, the first pattern and/or the second pattern, as well as the one or several parameters discussed above are chosen, and the corresponding predetermined references are set. These first and/or second patterns, parameters and predetermined refences are introduced as settings in the software.

[0046] A first pattern, which allows to identify defects in the needles 3, is identified in Fig. 6. This first pattern is formed by a plurality of spots 8, each of them corresponding to a reflexion of the light emitted by the lighting 13 on a portion of the needles 3 of the group 6. In the exemplary embodiment shown in the figures, each spot 8 corresponds to a reflexion of light in a curved surface of the hook 9 at the free end of the needle 3. The first pattern is formed by the eight aligned consecutive pots 8 in Fig. 6, starting from the rightmost spot 8. At least one parameter is chosen in the first pattern, and a predetermined reference is set for said parameter from Fig. 6 in which all the needles are free of defects. The parameter can be, for instance, one of the following:

- The number of spots 8. The predetermined reference is the value 8 (there must be eight spots).
- The shape of spots 8. The predetermined reference is an ellipsoidal shape, with its major axis vertically oriented, as can be seen in Fig. 6.
- The area of the spots 8. The predetermined reference is the area of the spot 8 measured in Fig. 6.
- The position of the spots 8. The predetermined reference is the X-Y position of a central point of the spot 8 in Fig. 6.
- A relative distance between two spots 8, for instance the relative distance between each pair of consecutive spots 8 in the alignment of spots 8. The predetermined reference is a relative distance between spots 8 measured in Fig. 6.

[0047] A second pattern, which allows to identify defects in the needles 3, is identified in Fig. 6. This second pattern is a line 11 corresponding to a reflexion of light in a length of yarn 7, said line 11 having one or several discontinuities 12, each of said discontinuities 12 corresponding to a section of said yarn 7 which passes through a hook 9 of a needle 3 of said group 6. In the exemplary embodiment shown in the figures, the line 11 is the short, interrupted line on the right area of Fig. 6. The line 11 has two discontinuities 12. At least one parameter is chosen in the second pattern, and a predetermined reference is set for said parameter from Fig. 6 in which all the needles are free of defects. The parameter can be, for instance, one of the following:

- The number of discontinuities 12. The predetermined reference is the value 2 (there must be two discontinuities).
- The length of discontinuities 12. The predetermined reference is the length of the discontinuity 12 measured in Fig. 6.
- The position of discontinuities 12. The predetermined reference is the X-Y position of a central point of the discontinuity 12 in Fig. 6.

[0048] The steps [a] to [e] of the method are carried out by the software for subsequent image frames 5 obtained from the digital camera 4 while the automatic knitting machine 1 is working manufacturing a knitted fabric. Steps [b] and [c] are carried out by an image recognition algorithm included in the software. The image frames 5 are taken at a suitable time rate, which is adjusted in function of the rotational speed of the rotating cylinder 14 and the gauge, so that in each image frame 5 all the needles 3 are at the same position. The time rate for taking the image frames 5 is also adjusted so that each needle 3 of the knitting machine 1 is contained in at least one of the image frames 5 and present in at least one of the first or the second pattern.

[0049] Figs. 7 and 8 are respectively equivalent to Figs. 5 and 6, but in this case one the needles 3 is broken, as can be seen in Fig. 7. The broken needle is the fourth from the left. The spot 8 corresponding to the broken needle is missing in the first pattern automatically detected in the processed image frame of Fig. 7. This is automatically recognised by the software which carries out steps [a]-[e], and which automatically determines the presence of a defect in the group 6 of needles 3 in step [e]. For instance, if the parameters chosen in the initial step are the number and the position of the spots 8, in step [d] the deviation consists in that the number of spots is seven instead of eight, and in that the fourth spot 8 from the left is not at its normal position; in the example of Figs. 7-8, the position of this spot 8 is completely lost. The deviation based on the position of the spot 8 allows to identify the faulty needle 3. On the other hand, the nature of the deviation allows to deduce the nature and the importance of the defect. The missing position of the fourth spot 8 indicates that the fourth needle has a defect and that this defect is very likely a broken needle or a hight offset of the needle, and therefore the defect in this needle is critical. The software issues an alarm causing an immediate stop of the knitting machine and indicating the number of the needle having a critical defect. The number of the needle refers to the position of said needle in the knitting machine. It is calculated by the software from the position on the needle in the image frame 5 and from a counting of the needles 3 passing through the image frame 5. It is also possible to automatically calculate and indicate the area of the knitted fabric which is probably affected by the faulty needle.

[0050] The same process can be applied to detect defects in the latch 10 of the needles 3. With this aim, the portion of the needle 3 with a curved surface, in which a reflexion of light occurs which corresponds to a spot 8, is chosen to be a portion of the latch 10 of the needle 3. The intensity of the light emitted by the lighting 13 and the absolute and relative positions of the lighting 13 and the digital camera 4 can be adjusted to obtain spots 8 corresponding to a reflexion of light on a portion of the latch 10 of the needles.

[0051] Figs. 9 and 10 are respectively equivalent to Figs. 5 and 6, but in this case the eighth needle from the left has lost its latch 10, as can be seen in Fig. 9. The corresponding discontinuity 12 in line 11 is missing in the second pattern in the processed image frame of Fig. 10. The method is the same as discussed above for the broken needle in Figs. 5-6. The lack of discontinuity 12 is automatically detected as a deviation of the parameter from the predetermined reference, and, as a result of step [e], the software issues an alarm causing an immediate stop of the knitting machine and indicating the number of the needle having the critical defect.

[0052] Non-critical defects in the needles 3 can also be automatically detected. For instance, if the position, the area or the shape of a spot 8 slightly differs from a predetermined reference, in step [e] the software automatically determines the presence of a non-critical defect in the corresponding needle 3 and shows a message indicating that the needle should be inspected as soon as possible. These non-critical defects can be, for instance, a moderate wear on the hooked end of the needle, a moderate offset of the whole needle or a moderate offset of the latch.

[0053] Figs. 11-14 are examples of real image frames 5 obtained from the digital camera 4 and treated in steps [a]-[e] as discussed above. Fig. 11 is an image frame 5 equivalent to Fig. 5. Figs. 12 and 14 are processed monochrome image frames 5 equivalent to those of Figs. 6 and 8. Fig. 13 is an enlarged portion of the image frame of Fig. 12. Steps [b] and [c] are preferably carried out on such enlarged portion of the image frame 5, which is focused on the area containing the first and/or the second pattern. In the example shown in Fig. 13, the enlarged portion contains the first pattern formed by eight aligned spots 8 and the second pattern formed by the line 11 with two discontinuities 12.

[0054] Figs. 15 to 20 refer to a second embodiment of the system according to the invention. The automatic knitting machine is also circular, but of the kind with one set of vertical needles and one set of horizontal needles for manufacturing a double jersey knit tubular fabric. More concretely, the automatic kitting machine used in the tests described below for Figs. 15 to 20 is a double jersey circular knitting machine, model of CANMARTEX-JUMBERCA brand, with 852x852 needles, diameter of 17 inches, and a 16 gauge (number of needles per inch). The vertical and horizontal needles 3 are arranged in a rotating cylinder, so that they travel along a circumference which is coaxial with the rotating cylinder. The needles 3 interact with cams which are statically arranged in a dial around the cylinder of needles, and which make each vertical needle 3 to move up and down and each horizontal needle 3 to move back and forth. The cylinder of needles, actuated by a motor, and the static cams are the actuating device referred to above for automatically moving the needles 3. Since the cams are static, each vertical needle 3 and each horizontal needle 3 travelling along the circumference has a unique position at each point of said circumference. The needles 3 are all identical. They are latch needles as described above and schematically shown in Figs. 3 and 4. The operation of this type of circular knitting machine with vertical and horizontal needles, as well as the movements of the vertical and horizontal latch needles to form the knit loops, are not described in greater detail here since they are well known to those skilled in the art.

[0055] The method and the system are equivalent to those described above for the first embodiment. A digital camera 4 and a controlled lighting 13 are also statically arranged so that image frames 5 of a group 6 of needles 3 are obtained from the digital camera 4. The steps [a]-[e] are essentially the same. The only difference is that the group 6 of needles 3 contains vertical needles and horizontal needles. The focus axis of the digital camera 4 is preferably in a 45° plane, bisector of the 90° angle formed by the vertical needles and the horizontal needles.

[0056] Fig. 15 is a schematic, idealized figure of an image frame 5 obtained from the digital camera 4 in step [a]. All the needles are without defects. Fig. 16 is a corresponding processed image frame 5 used in the subsequent steps of the method. The image frame 5 of Fig 16 is obtained before step [b] by oversaturating and transforming to monochrome an image frame equivalent to Fig. 15 obtained from the digital camera 4 in step [a]. The steps [b]-[e] of the method are carried out for each of the two rectangular areas shown in Fig. 17. The upper and lower rectangular areas contain the free hooked ends of, respectively, the horizontal needles 3 and the vertical needles 3, including the end of the latches 10. Fig. 18 and 19 respectively show an enlarged view of the upper and the lower rectangular areas. As can be seen in these figures, the dots corresponding to the free hooked ends of the needles 3 are clearly recognisable, so that the first pattern can be recognised. The method for automatically recognize defects in the needles 3 from the first pattern is equivalent to the one described above for the first embodiment. In Figs. 18 and 19 a final portion of the latches 10 is also recognisable as smaller spots which are adjacent to the bigger spots corresponding to the end of the needles. Both the final portion of the latches 10 and the end of the needles 3 can be included in the first pattern, allowing to defect defects in the latches by using this first pattern. It is also possible to recognise the second pattern by focusing the digital camera 4 on a different area of a group 6 of needles 3 in which the yarn 7 is fed to the needles 3 (not shown in the figures).

[0057] The system and the method according to the invention as described above for two exemplary embodiments can automatically detect at least the following defects in the needles:

- the needle is broken;
- the hooked end of the needle is worn due to friction with the yarn;
- the hooked end of the needle is transversally or axially offset because the needle is bent;
- the latch of the needle is broken or missing;
- the latch of the needle is transversally or axially offset because the latch is bent or its pivot axis has moved.

[0058] Each of these defects is automatically recognised because it causes a change in the reflexion of light on the needles or on the yarn, which in turn causes a change in the first or the second pattern which is recognised by an image recognition software. As discussed above, the system and the method according to the invention allow to automatically recognize whether the defect is critical (a faulty needle which is very likely causing a defect in the knitted fabric) or non-critical (a defect in a needle which is probably not yet causing a defect in the knitted fabric but that requires the identified needle to be inspected as soon as possible).

[0059] The invention is not limited to large diameter circular knitting machines as described above for two exemplary embodiments, producing weft knitted tubular fabric in continuous lengths of constant width, but also applies to other kind of automatic knitting machines like, for instance, small diameter circular weft knitting machines and flat knitting machines producing garment-length sequences of knitted fabric.

Claims

1. Method for detecting defects in the needles of an automatic knitting machine (1), said automatic knitting machine (1) comprising a plurality of yarn feeders (2), a plurality of movable needles (3), each of said needles (3) being adapted to subsequently catch and free a yarn provided by one of said yarn feeders (2) when said needle (3) is moved, and an actuating device for automatically moving said needles (3) according to a preestablished pattern for manufacturing a knitted fabric from the yarns provided by said yarn feeders (2); **characterized in that** a digital camera (4) is arranged to capture digital

image frames (5) of a group (6) of said needles (3) while said automatic knitting machine (1) is working manufacturing said knitted fabric, the needles (3) being adjacent to each other in said group (6);
and **in that** said method comprises the following steps:

[a] obtaining from said digital camera (4) image frames (5) containing at least portions of the needles (3) of said group (6) while said automatic knitting machine (1) is working manufacturing said knitted fabric;
[b] performing an automatic image recognition in said image frame (5) to determine at least one between a first pattern jointly defined by at least portions of the needles (3) of said group (6) and a second pattern defined by a length of at least one yarn (7) that interacts with at least one of the needles (3) of said group (6);
[c] automatically deriving from said first or second pattern at least one parameter related to the presence, the position or the shape of said needles (3) or portions of said needles (3) in said group (6);
[d] automatically calculating a deviation of said at least one parameter from a predetermined reference;
[e] in function of said deviation, automatically determining the presence of a defect in said group (6) of needles (3).

2. Method according to claim 1, wherein said first pattern determined in step [b] comprises a plurality of spots (8) in said image frame (5), each of said spots (8) corresponding to a reflexion of light in a portion of a needle (3) of said group (6).

3. Method according to claim 2, wherein said parameter automatically derived from said first pattern in step [c] comprises at least one of the group consisting of the number of said spots (8) in said first pattern, the shape of said spots (8), the area of said spots (8), the position of said spots (8) in said image frame (5) and a relative distance between two of said spots (8).

4. Method according to any of claims 2 to 3, wherein each of said spots (8) corresponds to a reflexion of light in a curved surface of a portion of each of said needles (3).

5. Method according to claim 4, wherein said portion of the needle (3) with a curved surface, in which a reflexion of light occurs which corresponds to said spot (8), is chosen to be a hook (9) adapted to subsequently catch and free a yarn when said needle (3) is moved.

6. Method according to any of claims 4 or 5, wherein said portion of the needle (3) with a curved surface, in which a reflexion of light occurs which corresponds to said spot (8), is chosen to be at a free end of said needle (3).

7. Method according to claim 4, wherein the needles (3) are latch needles, and said portion of the needle (3) with a curved surface, in which a reflexion of light occurs which corresponds to said spot (8), is chosen to be a portion of a latch (10) of the needle (3).

8. Method according to any of claims 1 to 7, wherein said second pattern determined in step [b] comprises a line (11) corresponding to a reflexion of light in said length of yarn (7), said line (11) having one or several discontinuities (12), each of said discontinuities (12) corresponding to a section of said yarn (7) which passes through a hook (9) of a needle (3) of said group (6).

9. Method according to claim 8, wherein said parameter automatically derived from said second pattern in step [c] comprises at least one of the group consisting of the number of said discontinuities (12), the length of said discontinuities (12) and the position of said discontinuities (12) in said image frame (5).

10. Method according to any of claims 1 to 9, wherein, before step [b], said image frames (6) obtained in step [a] are transformed to monochrome images.

11. Method according to any of claims 1 to 10, wherein a controlled lighting (13) is focused on said group (6) of needles (3).

12. Method according to any of claims 1 to 11, wherein, when in step [e] the presence of a defect is automatically detected in said group (6) of needles (3), and a needle (3) in which said defect is present is automatically identified in function of said parameter that has been automatically derived in step [c].

13. Method according to any of claims 1 to 12, wherein said automatic knitting machine (1) is a circular knitting machine in which said needles (3) are arranged in a rotating cylinder (14) which make said needles (3) to travel along a circumference which is coaxial with said rotating cylinder (14), and wherein said digital camera (4) is statically arranged, so that it does not rotate with said rotating cylinder (14), and said digital image frames (5) include a portion of said circumference.

14. System for detecting defects in the needles of an automatic knitting machine (1), comprising an automatic knitting machine (1) with a plurality of yarn feeders (2), a plurality of movable needles (3), each of said needles (3) being adapted to subsequently

catch and free a yarn provided by one of said yarn feeders (2) when said needle (3) is moved, and an actuating device for automatically moving said needles (3) according to a preestablished pattern for manufacturing a knitted fabric from the yarns provided by said yarn feeders (2); **characterized in that** it further comprises:

- a digital camera (4) arranged to capture digital image frames (5) of a group (6) of said needles (3) while said automatic knitting machine (1) is working manufacturing said knitted fabric, the needles (3) being adjacent to each other in said group (6);
- a processor (14) connected to said digital camera (4);
- a computer program comprising instructions which, when executed by said processor (14), cause said processor (14) to carry out the following steps:

  [a] obtaining from said digital camera (4) image frames (5) containing at least portions of the needles (3) of said group (6) while said automatic knitting machine (1) is working manufacturing said knitted fabric;
  [b] performing an automatic image recognition in said image frame (5) to determine at least one between a first pattern jointly defined by at least portions of the needles (3) of said group (5) and a second pattern defined by a length of at least one yarn (7) that interacts with at least one of the needles (3) of said group (5);
  [c] automatically deriving from said first or second pattern at least one parameter related to the presence, the position or the shape of said needles (3) or portions of said needles (3) in said group (6);
  [d] automatically calculating a deviation of said at least one parameter from a predetermined reference;
  [e] in function of said deviation, automatically determining the presence of a defect in said group (6) of needles (3).

15. Computer program for detecting defects in the needles of an automatic knitting machine (1), said computer program comprising instructions which, when executed by a processor (15), cause said processor (15) to carry out the following steps:

[a] obtaining from a digital camera (4) image frames (5) containing at least portions of the needles of a group (6) of needles (3) of an automatic knitting machine (1), wherein sad image frames have been taken by said digital camera (4) while said automatic knitting machine (1) is working manufacturing a knitted fabric;
[b] performing an automatic image recognition in said image frame (5) to determine at least one between a first pattern jointly defined by at least portions of the needles (3) of said group (5) and a second pattern defined by a length of at least one yarn (7) that interacts with at least one of the needles (3) of said group (5);
[c] automatically deriving from said first or second pattern at least one parameter related to a state of said needles (3) or portions of said needles (3) in said group (6);
[d] automatically calculating a deviation of said at least one parameter from a predetermined reference;
[e] in function of said deviation, automatically determining the presence of a defect in said group (6) of needles (3).

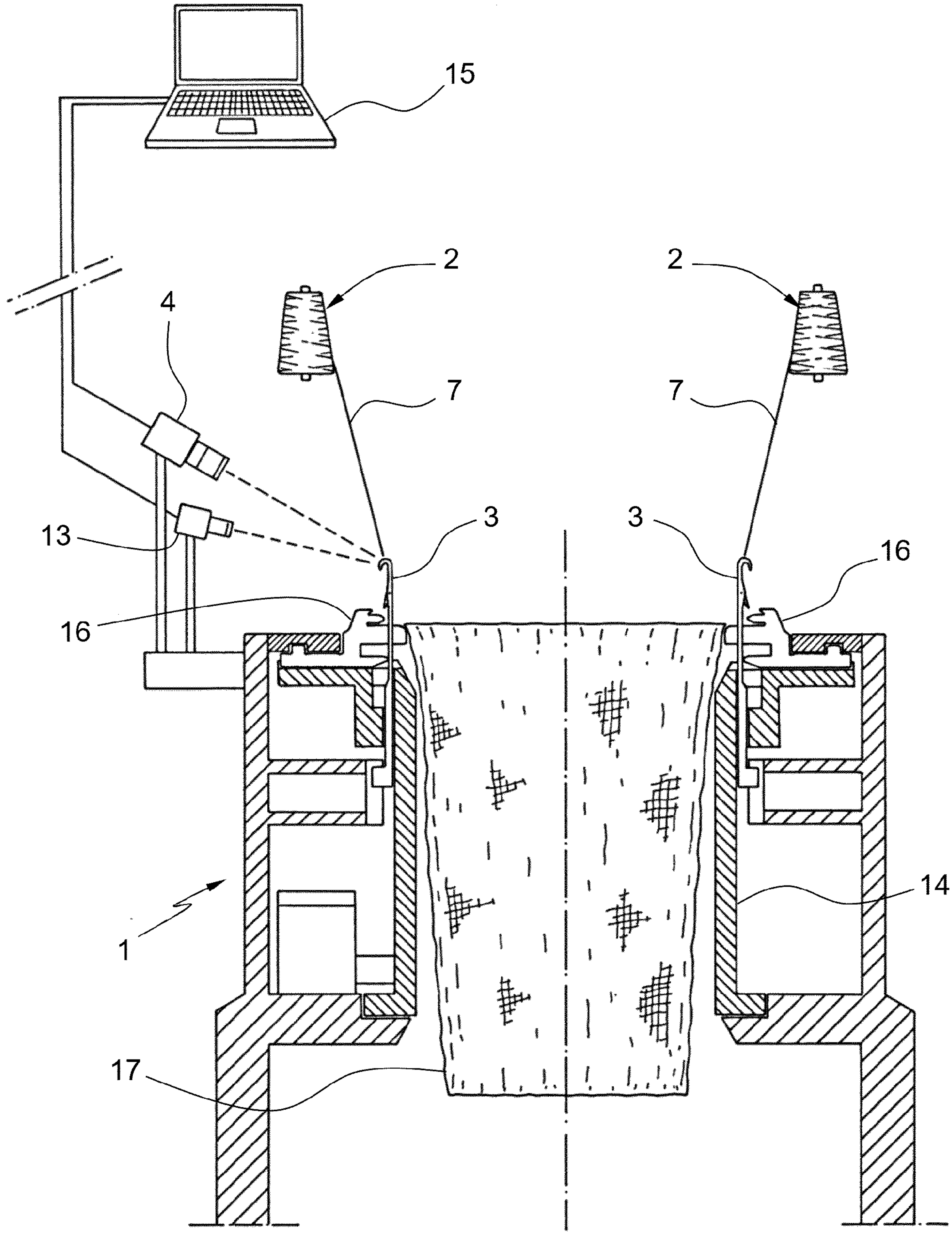

FIG. 1

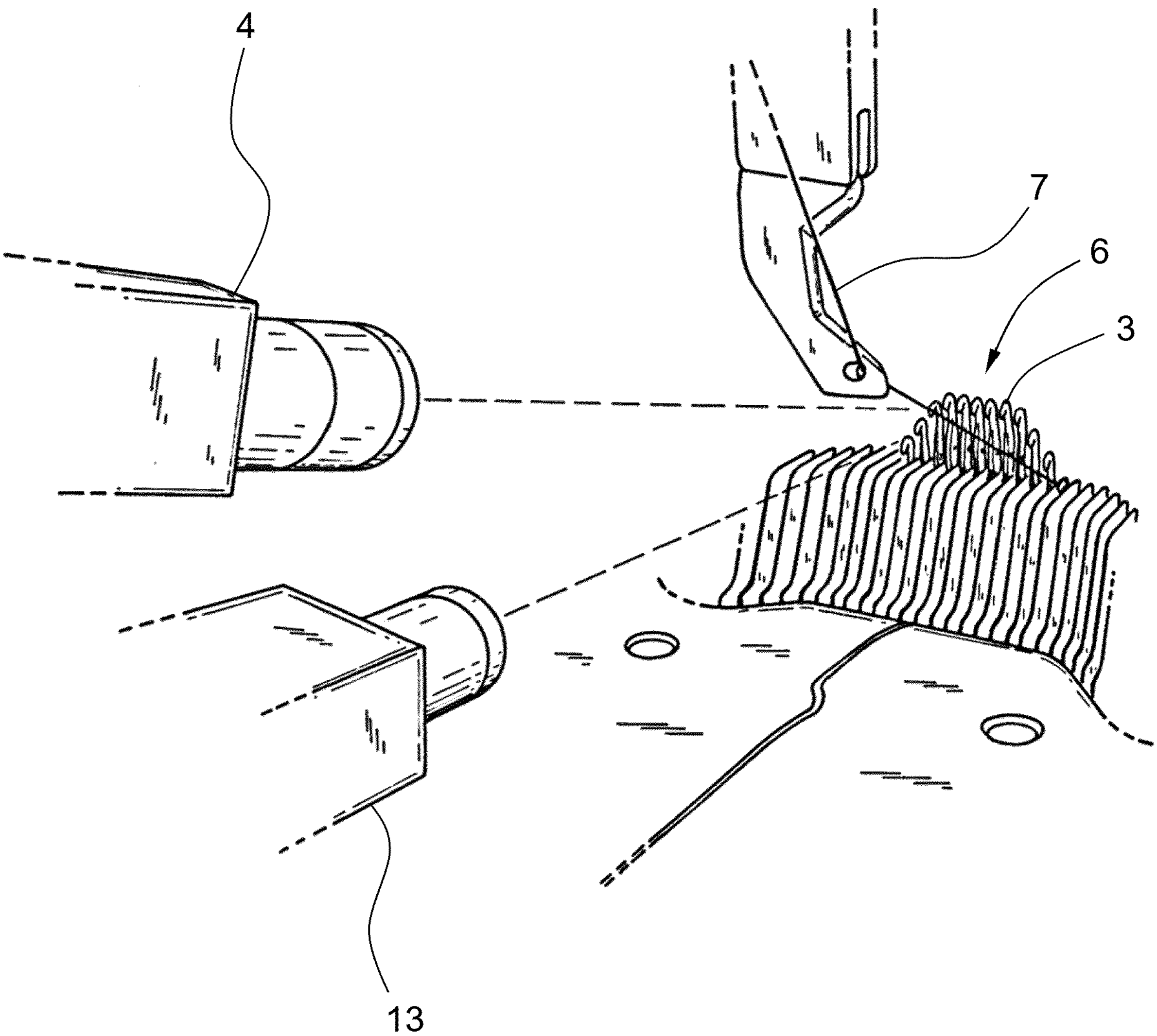

FIG. 2

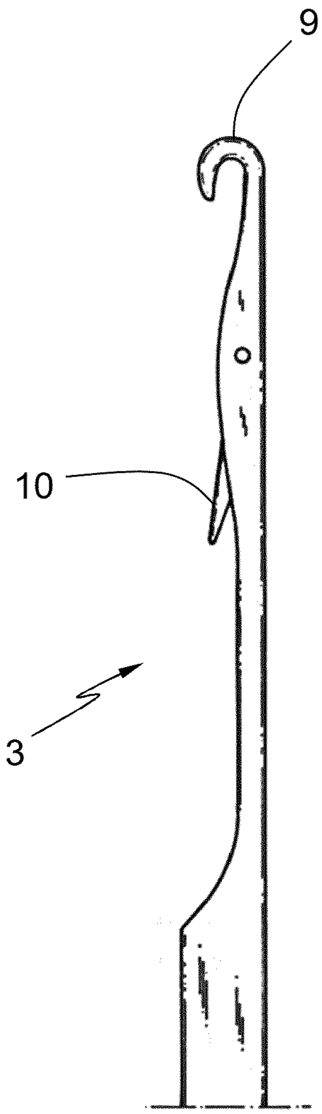

FIG. 3

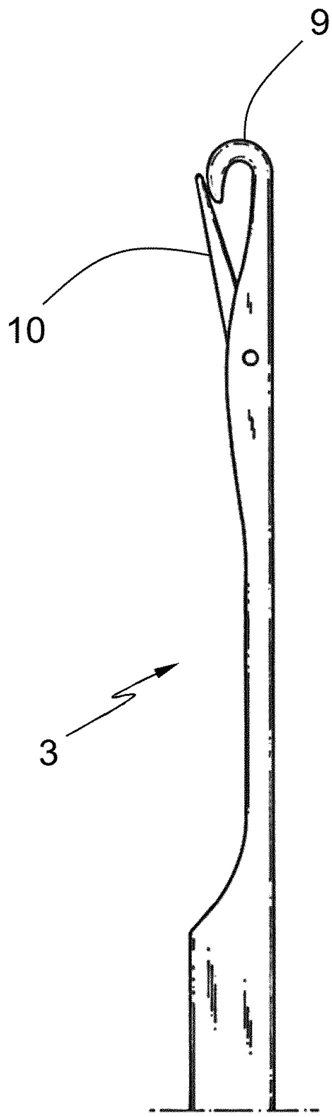

FIG. 4

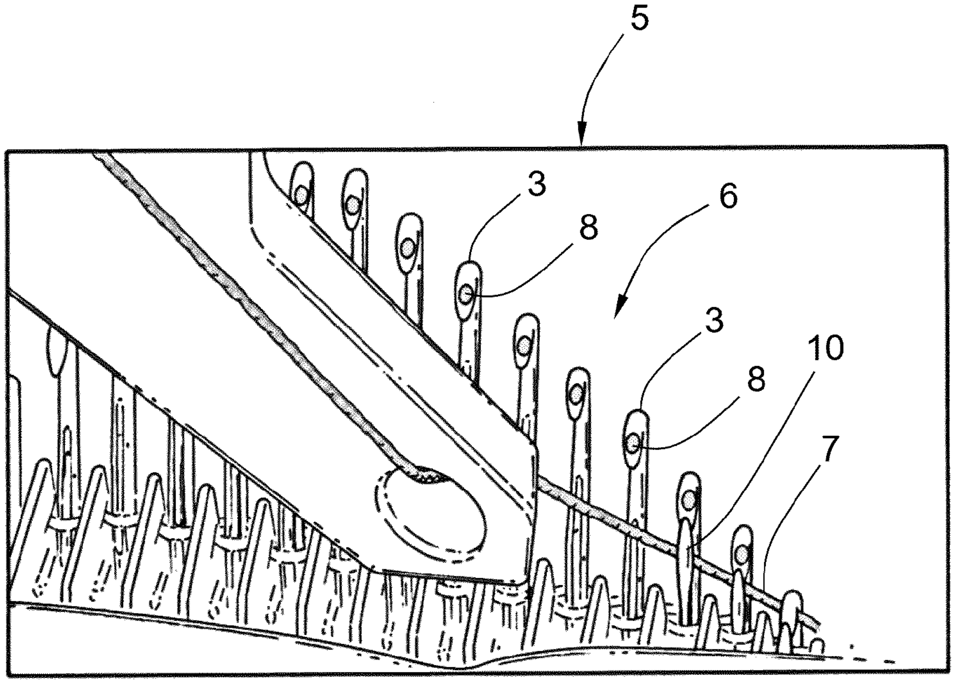

FIG. 5

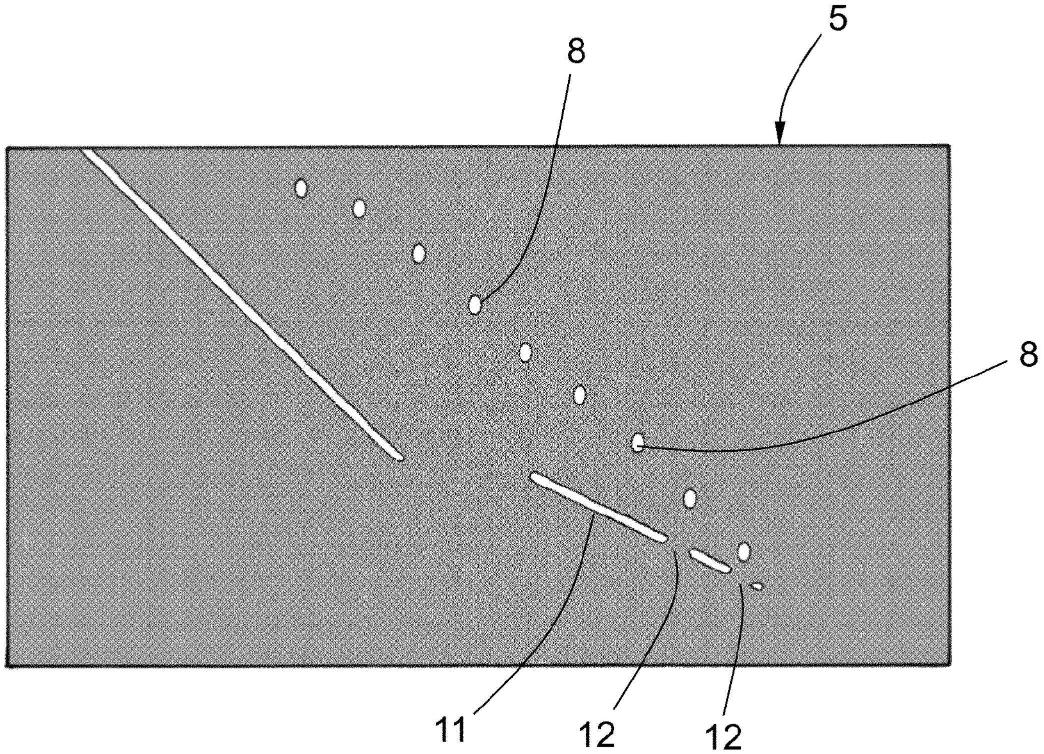

FIG. 6

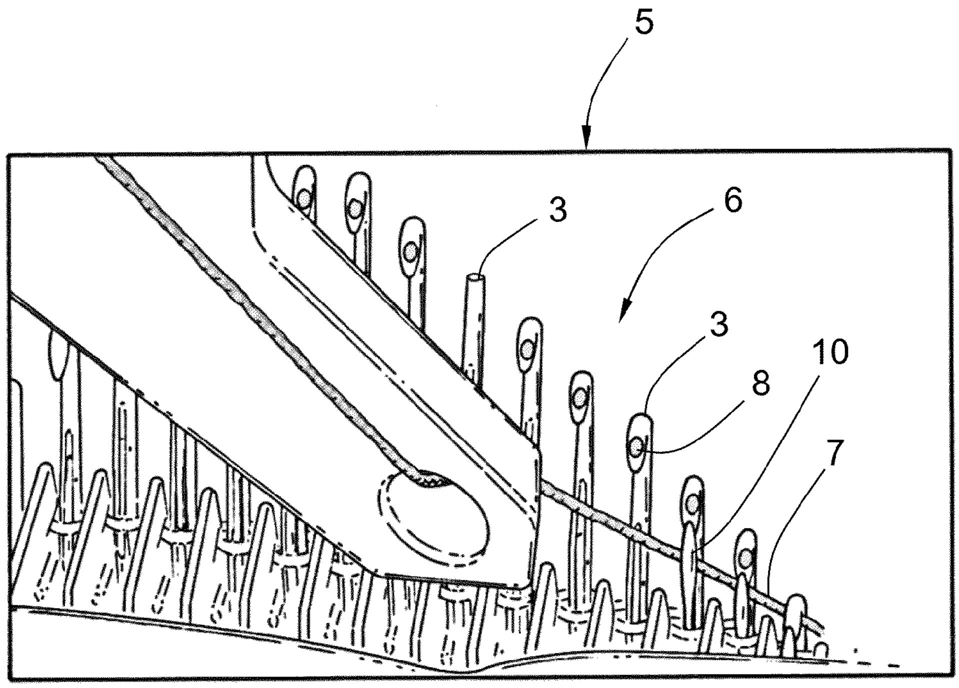

FIG. 7

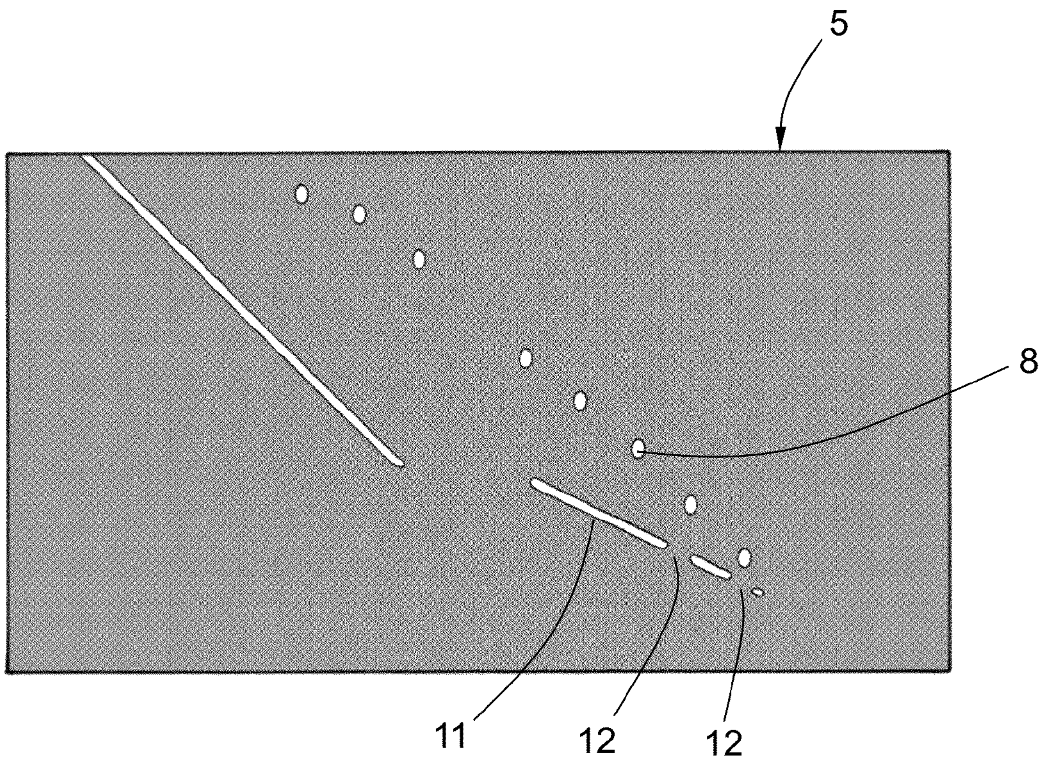

FIG. 8

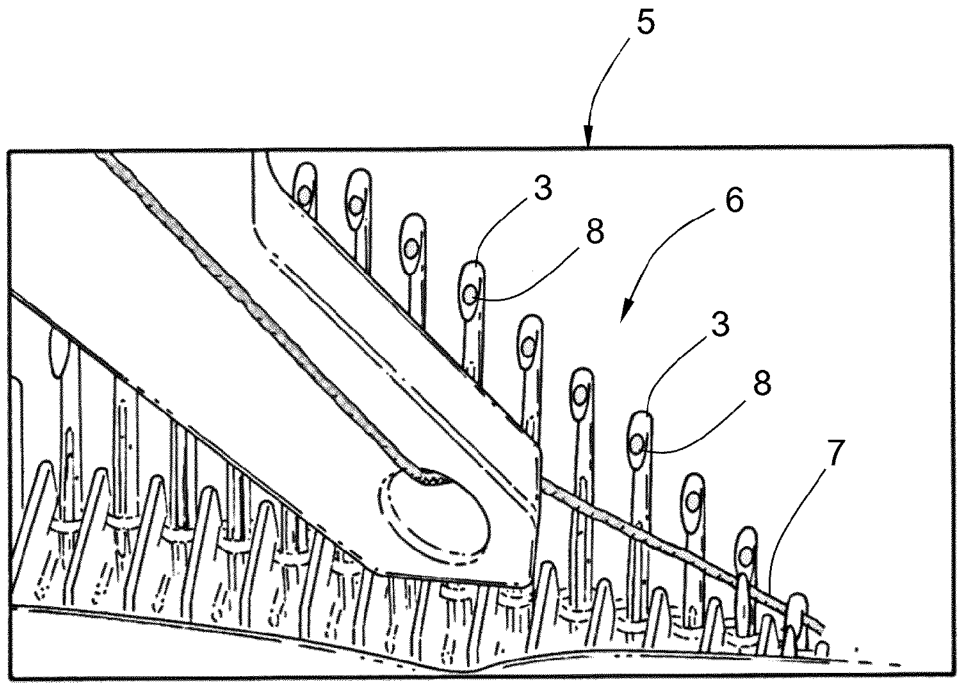

FIG. 9

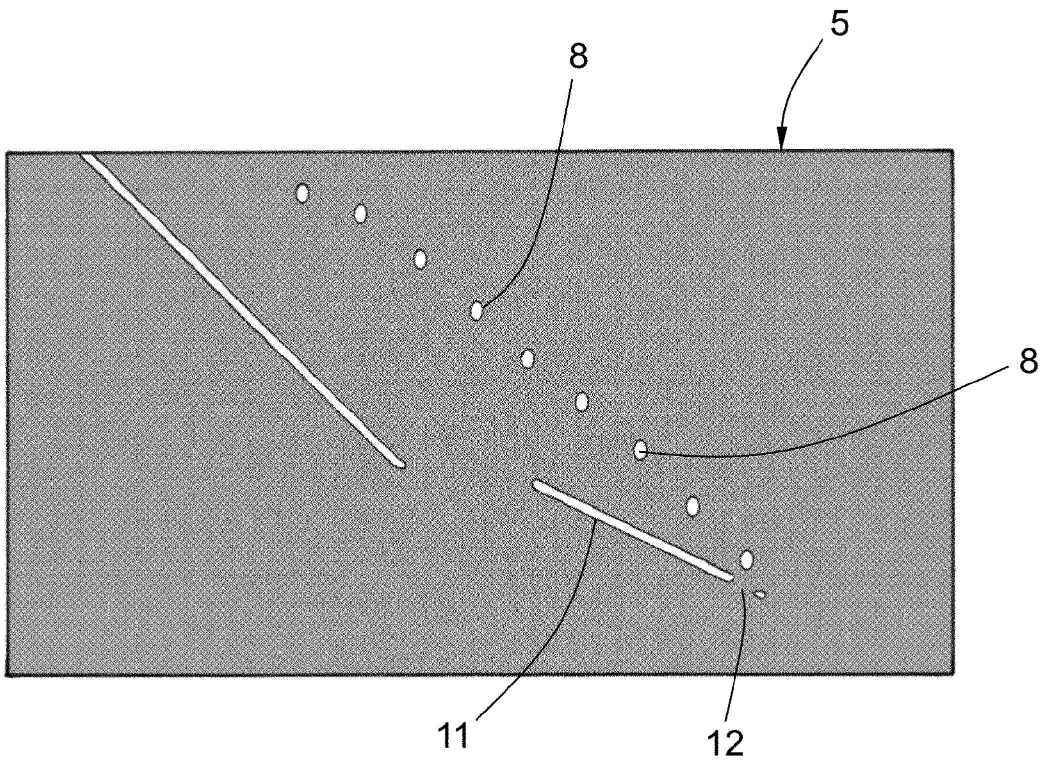

FIG. 10

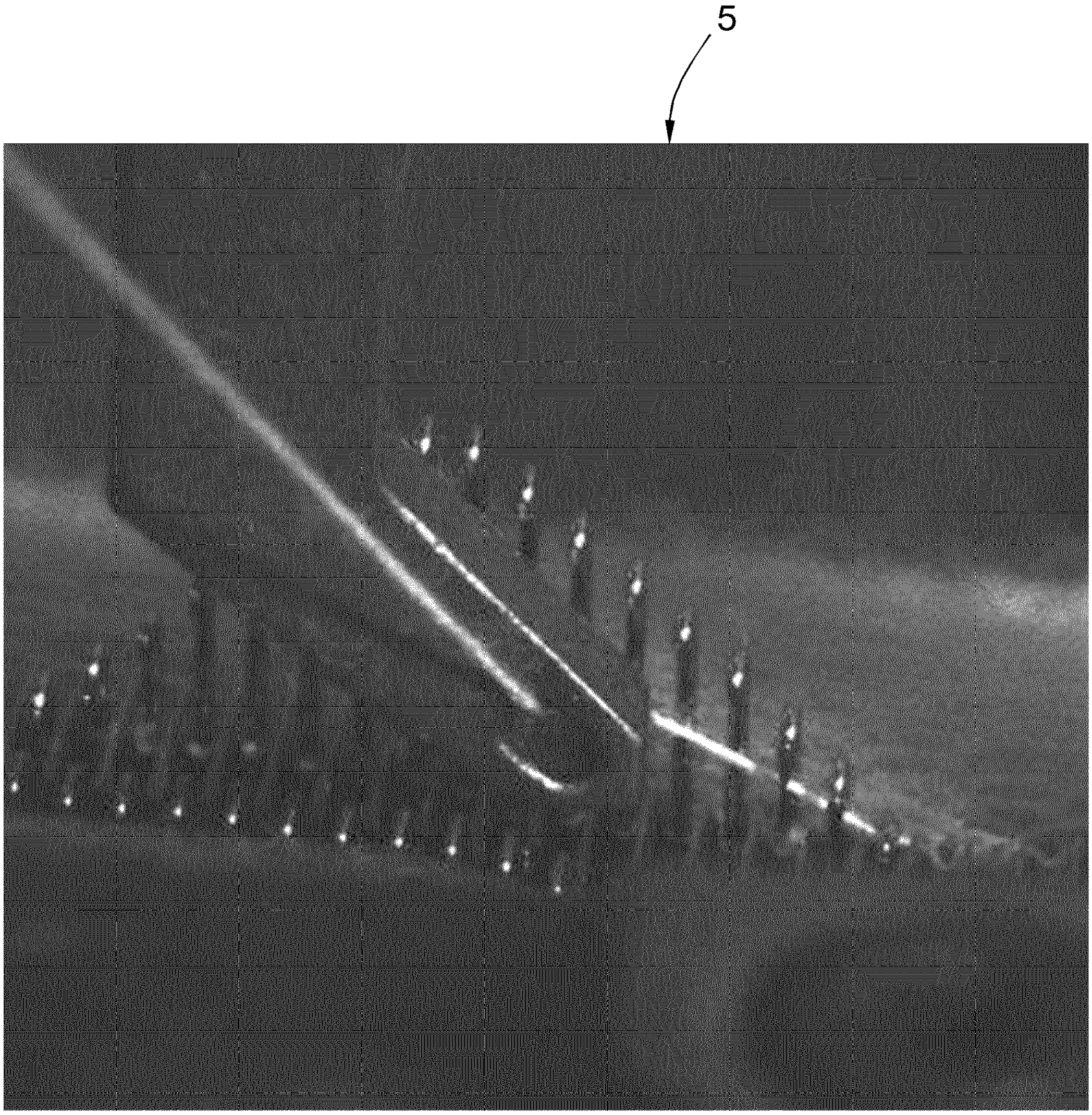

FIG. 11

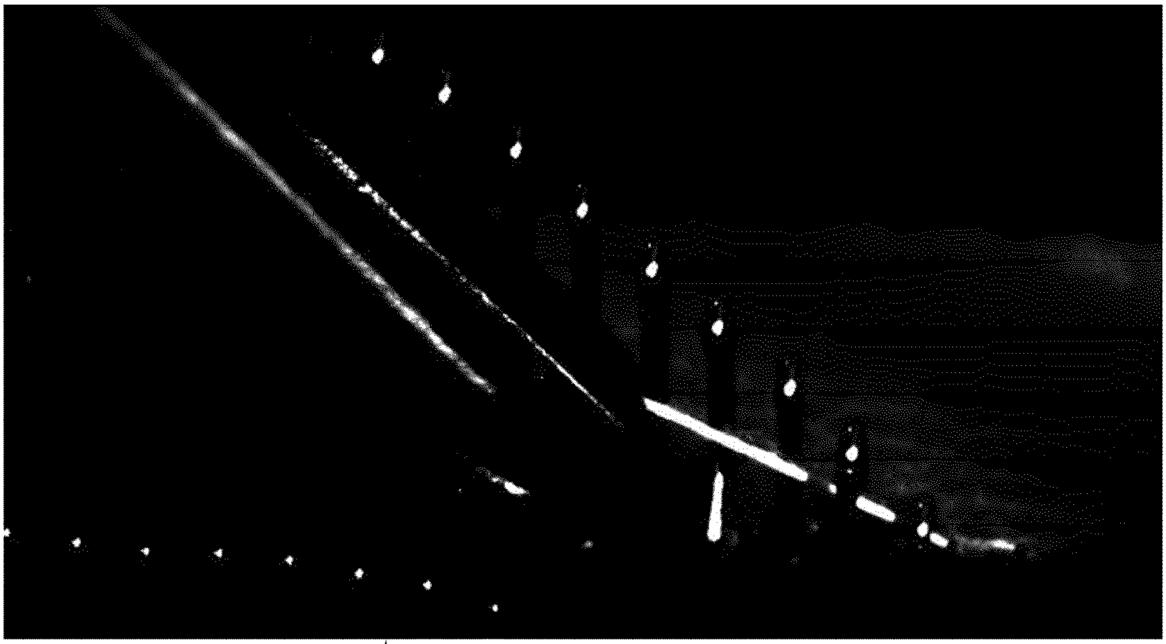

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FIG. 12

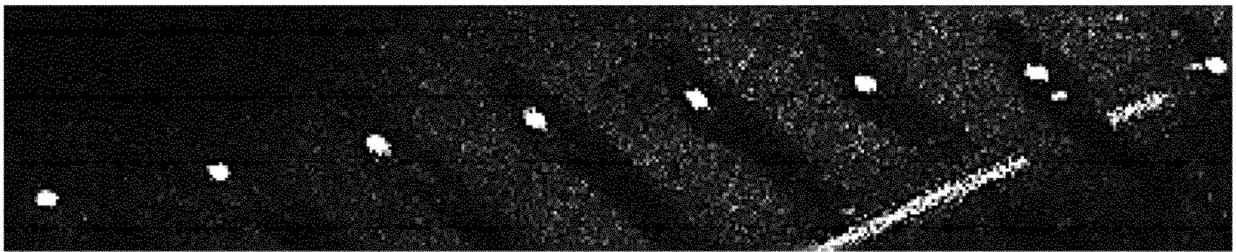

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FIG. 13

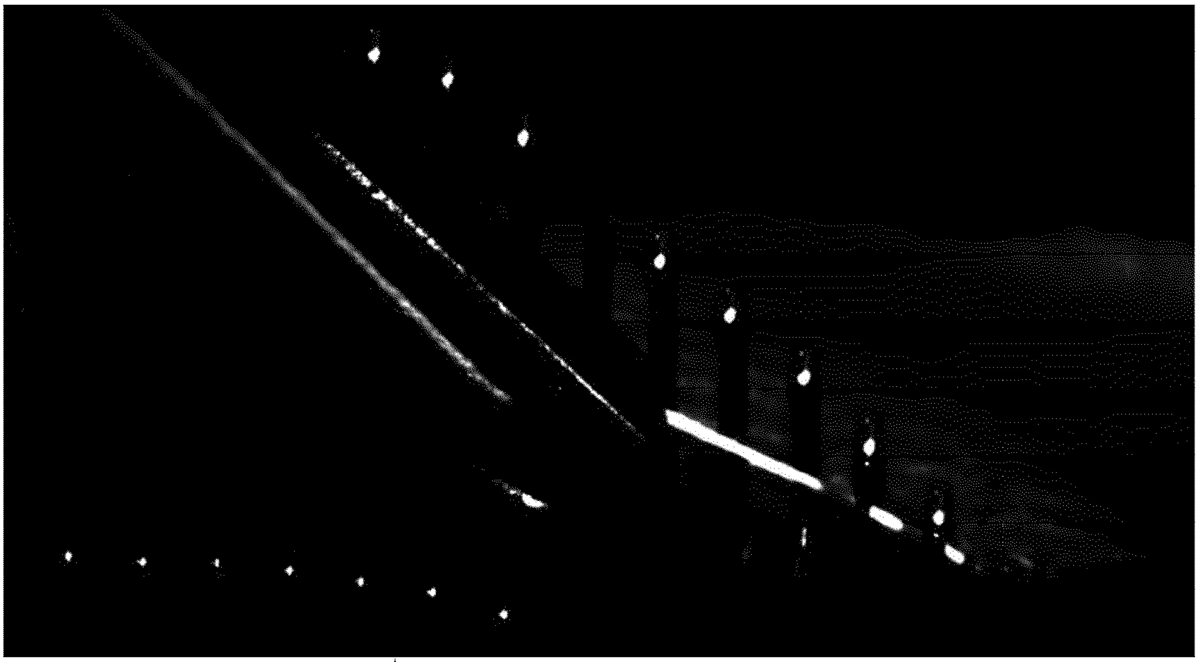

FIG. 14

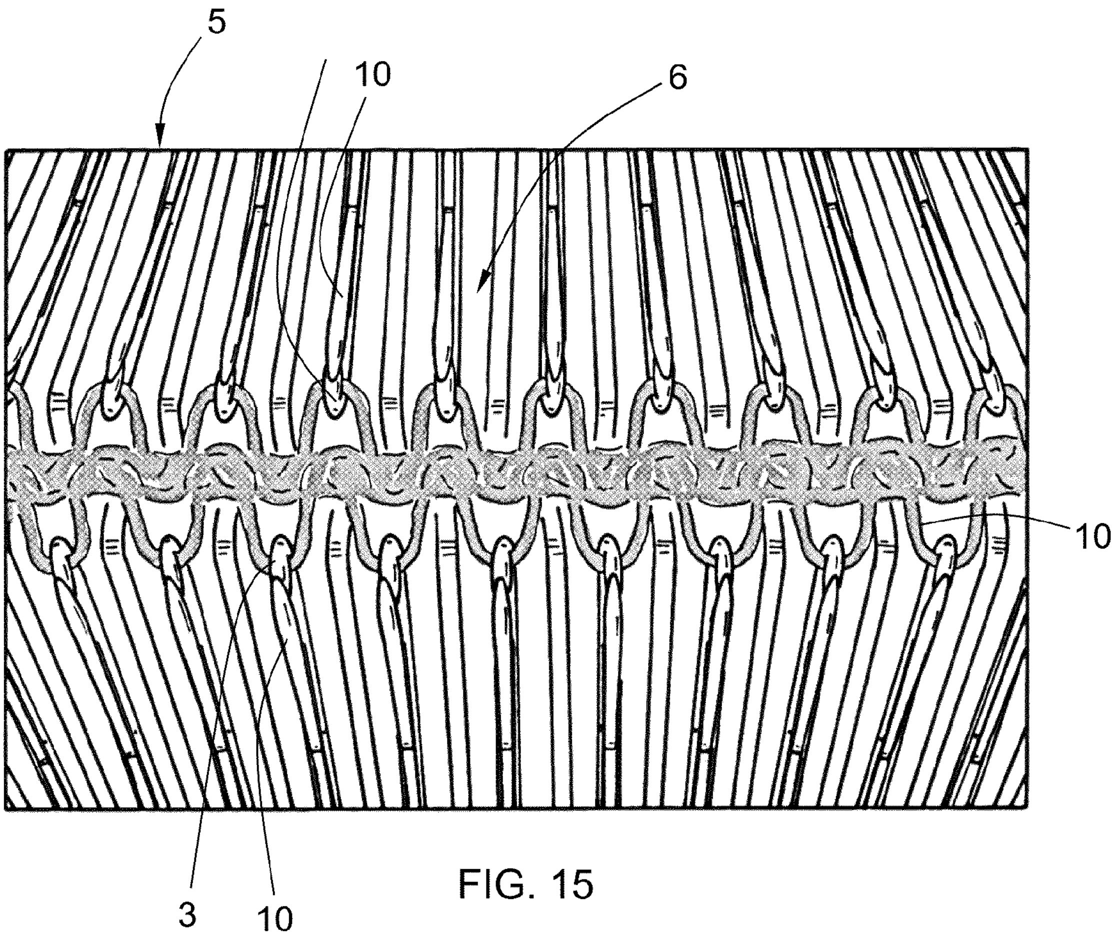

FIG. 15

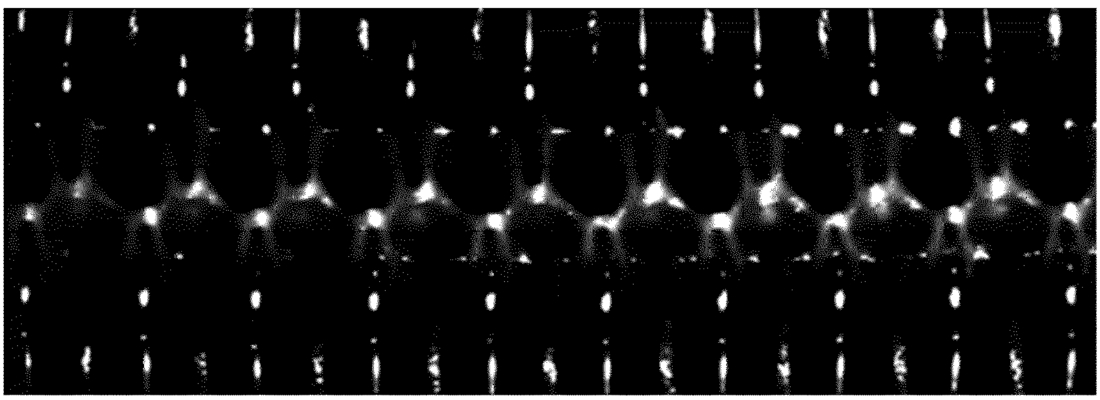

FIG. 16

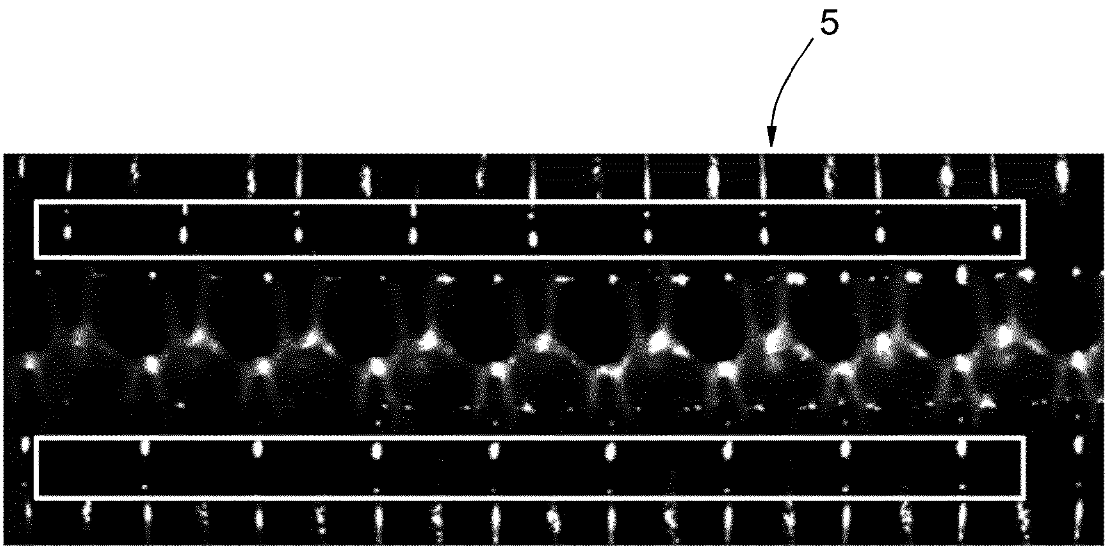

FIG. 17

FIG. 18

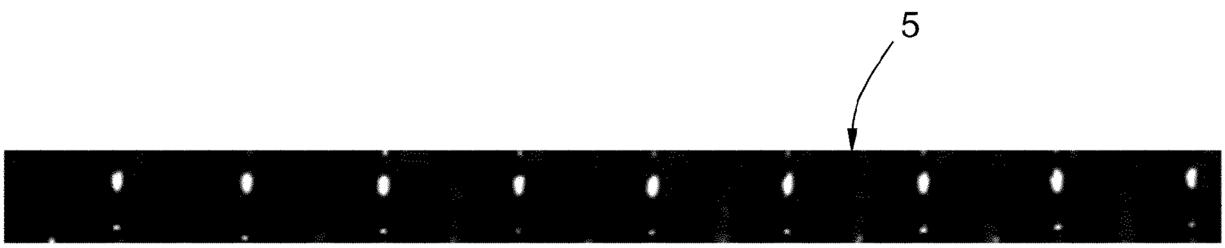

FIG. 19

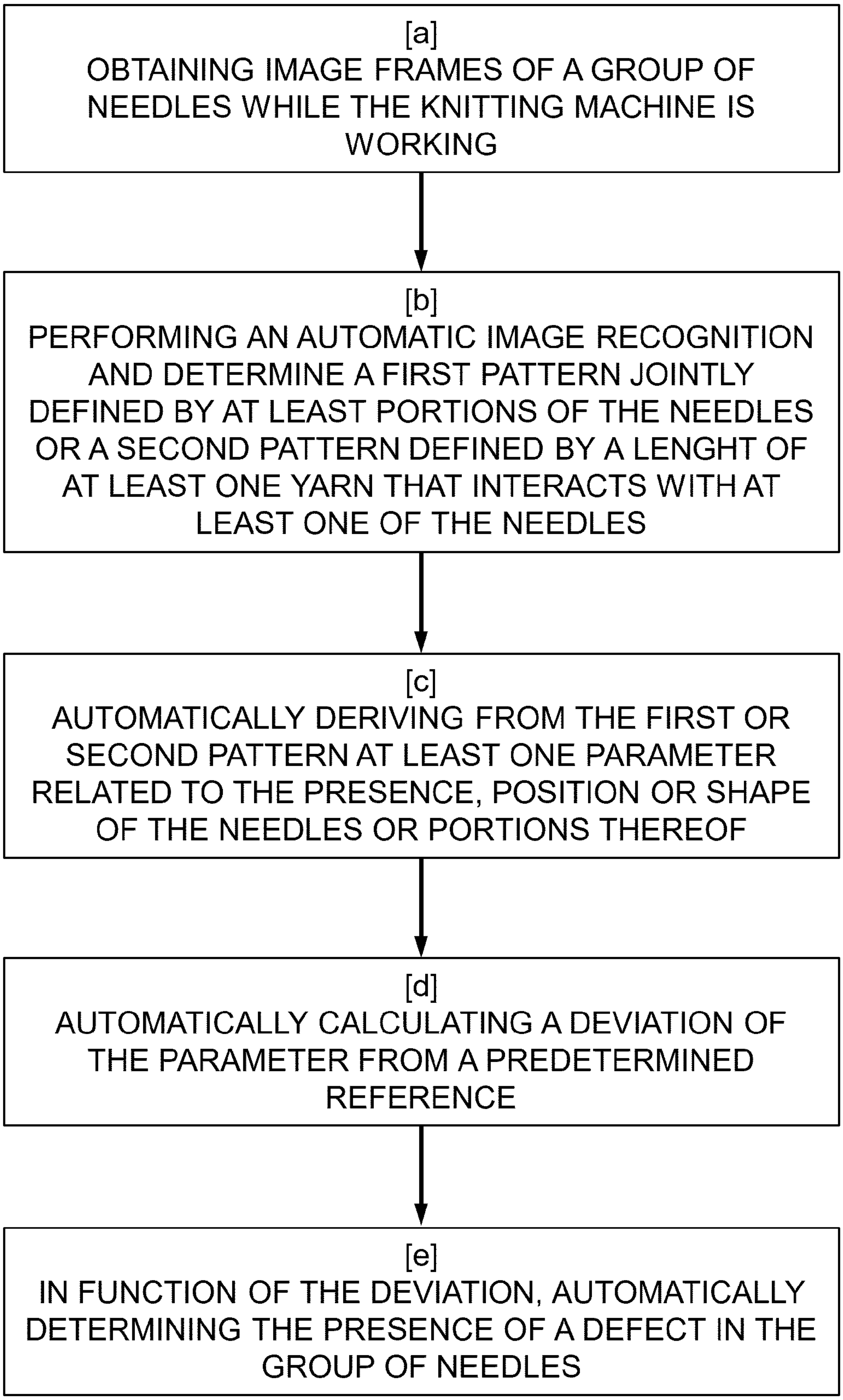
[a]
OBTAINING IMAGE FRAMES OF A GROUP OF NEEDLES WHILE THE KNITTING MACHINE IS WORKING
[b]
PERFORMING AN AUTOMATIC IMAGE RECOGNITION AND DETERMINE A FIRST PATTERN JOINTLY DEFINED BY AT LEAST PORTIONS OF THE NEEDLES OR A SECOND PATTERN DEFINED BY A LENGHT OF AT LEAST ONE YARN THAT INTERACTS WITH AT LEAST ONE OF THE NEEDLES
[c]
AUTOMATICALLY DERIVING FROM THE FIRST OR SECOND PATTERN AT LEAST ONE PARAMETER RELATED TO THE PRESENCE, POSITION OR SHAPE OF THE NEEDLES OR PORTIONS THEREOF
[d]
AUTOMATICALLY CALCULATING A DEVIATION OF THE PARAMETER FROM A PREDETERMINED REFERENCE
[e]
IN FUNCTION OF THE DEVIATION, AUTOMATICALLY DETERMINING THE PRESENCE OF A DEFECT IN THE GROUP OF NEEDLES

FIG. 20

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EUROPEAN SEARCH REPORT

Application Number
EP 22 38 3327

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X,D A	CN 109 881 356 A (UNIV XIAN POLYTECHNIC) 14 June 2019 (2019-06-14) * paragraphs [0025] - [0040]; claims 1, 3; figures 1, 2 *	1-13 14,15	INV. D04B37/02 D04B35/18
X A	CN 110 987 148 A (UNIV ZHEJIANG SCIENCE & TECH) 10 April 2020 (2020-04-10) * paragraphs [0031], [0032], [0038] - [0057]; figure 1 *	1-13 14,15	
A	KR 2019 0032931 A (PARK SANG MIN [KR]) 28 March 2019 (2019-03-28) * paragraph [0043]; figures 5, 6 *	1-15	

TECHNICAL FIELDS SEARCHED (IPC)

D04B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	31 May 2023	Kirner, Katharina

CATEGORY OF CITED DOCUMENTS

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31-05-2023

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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CN 110987148 A	10-04-2020	NONE	
KR 20190032931 A	28-03-2019	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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- CN 109881356 A **[0008]**
- WO 2020079493 A1 **[0009]**