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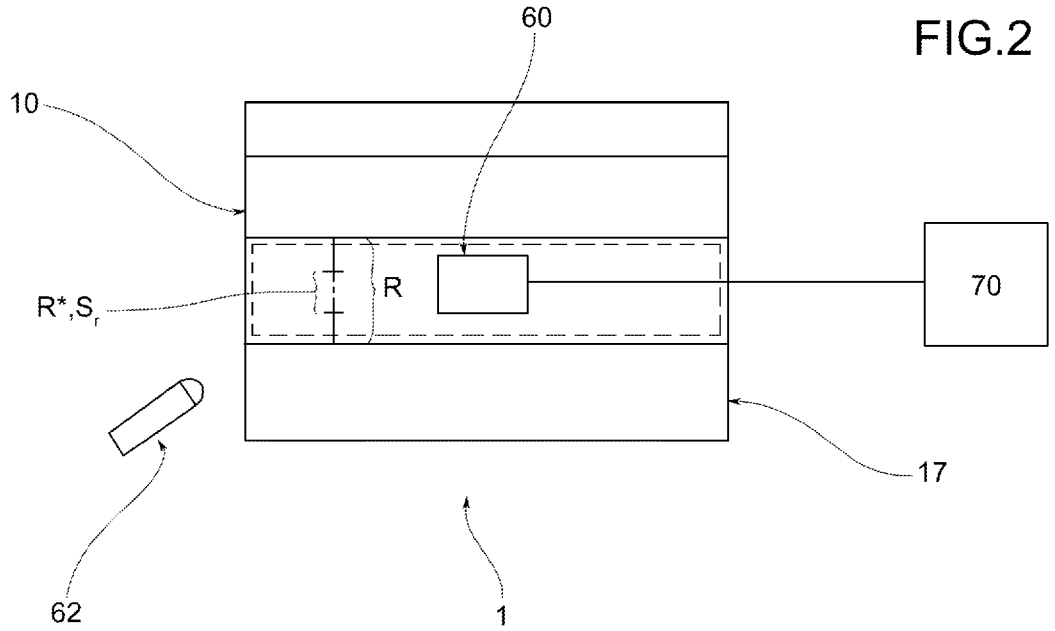
(54) Title: APPARATUS AND METHOD FOR CONTINUOUS DETECTION OF DEFECTS IN A YARN IN A SPINNING MACHINE

FIG.2



(57) Abstract: An apparatus for detecting defects in a drawn roving (R) being processed in a spinning machine comprises acquisition means (60), and processing means (70) for digitally processing acquired images (I) and detecting defects by means of a machine learning detection algorithm.

[Continued on next page]

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"APPARATUS AND METHOD FOR CONTINUOUS DETECTION OF DEFECTS IN A YARN IN A SPINNING MACHINE"

DESCRIPTION

[0001] This invention is in the field of textile fiber processing, and in particular in the field of instruments and methods for detecting defects in the products of spinning preparation processes. In particular, are objects of the present invention a method and an apparatus for detecting tangles or knots, usually referred to as "neps," in the yarn produced in a ring-spinning machine.

[0002] As is well known, a spinning machine is capable of processing bobbins of roving to obtain spools of yarn, after having drawn and twisted the roving.

[0003] To this end, the spinning machine consists of a frame extending along a longitudinal axis and supporting a creel from which the bobbins of roving are hung, a drawing device supported by the frame, consisting of a set of coupled cylinders having a longitudinal extension, between which the roving to be drawn passes, and a rail carrying the spindles, in a row along the longitudinal axis, rotating about its vertical axis, from which the drawn and twisted yarn is wound.

[0004] It is well known how imperfections in the yarn cause unpleasant effects in the appearance of the fabric,

especially in the case of colored fabrics. For this reason, there is a strong need in the industry to monitor the extent and frequency of imperfections, and in particular fiber tangles.

[0005] To date, there are two industrial methodologies for detecting defects in yarn.

[0006] A first method provides for analyzing in the laboratory a sample consisting of the yarn of some spools removed from the spinning machine, generally by means of capacitive sensors capable of detecting the variation of mass along the yarn, thus defining the type and frequency of tangles; this method is generally reliable, but does not allow for intervening on the processing parameters to improve the quality of the yarn, nor for understanding the causes of defects found, because it is performed after finishing the production of the yarn. For example, the USTER® Tester 5-S800, manufactured and marketed by Uster Technologies AG, is often used.

[0007] A second method involves the use of detection modules, based on capacitive or optical sensors, arranged at the spindles for winding the yarn, equipped with blades capable of physically eliminating tangles from the yarn. Even in this case, it is not possible to trace the causes that generated the defect and intervene accordingly.

[0008] Other methodologies are applied in the yarn winding phase, a process that takes place downstream of the spinning machines; for example, the Uster® Quantum 3 tester, based on capacitive sensors, produced and marketed by Uster Technologies AG, and the YarnMaster Prisma tester, based on optical sensors, produced and marketed by Loepfe Brothers Ltd, are widely used.

[0009] A first object of this invention, moreover, is to detect defects in a yarn in a spinning machine, in order to modify the processing parameters of the spinning machine or other upstream machines or maintenance procedures, so as to obtain a better quality yarn.

[0010] The aforesaid methodologies are not suitable for this object, partly because they use capacitive or optical sensors that require a regular yarn feed.

[0011] Between the drawing device and the winding device of the spinning machine, however, the yarn undergoes strong oscillations, due to the winding and twisting actions that take place downstream.

[0012] Some studies also involve the use of image acquisition via a video camera, and then processing of the images in order to detect tangles. For example, some methodologies are described in the following articles:

- Li Z, Pan R and Gao W. Formation of digital yarn black board using sequence images. Textile Research Journal.

2016; 86: 593-603;

- Eldessouki M, Ibrahim S and Militky J. A dynamic and robust image processing based method for measuring the yarn diameter and its variation. Textile Research Journal. 2014; 84: 1948-60;

- Ling C, Lianying Z, Li C and Xuanli Z. Digital image processing of cotton yarn seriplane. 2010 International Conference on Computer and Information Application. 2010, p. 274-7;

- Li Z, Xiong N, Wang J, Pan R, Gao W and Zhang N. An intelligent computer method for automatic mosaic of sequential slub yarn images based on image processing. Textile Research Journal. 2018; 88: 2854-66;

- Carvalho V, Soares F and Vasconcelos R. Artificial intelligence and image processing based techniques: A tool for yarns parameterization and fabrics prediction. 2009 IEEE Conference on Emerging Technologies & Factory Automation. 2009, p. 1-4.

[0013] However, these methods are not suitable for the intended industrial purposes since they involve the use of a pre-tensioned yarn with a regular feed.

[0014] Finally, some solutions are illustrated, for example, in patent documents CN-A-111235709, CN-A-109389583, CN-A-105386174, DE102018111648A1, WO2019130209A3, JP2018178282A, and DE102016121662A1.

[0015] Furthermore, the solutions known today are also unsatisfactory in terms of the reliability of the results. In effect, often some slight irregularities of the fibers, such as a slight enlargement of the fibers in one region, are mistakenly identified as tangling or another defect.

[0016] It is the object of this invention to provide a method and apparatus for detecting defects in a yarn being processed in a spinning machine, which satisfies the requirements of the industry and overcomes the drawbacks discussed above with reference to the prior art.

[0017] This object is achieved by a method according to claim 1 and an apparatus according to claim 17. The claims dependent thereon identify additional advantageous embodiments of the invention.

[0018] The features and advantages of the method and the apparatus according to this invention will be apparent from the description below, given by way of non-limiting example in accordance with the figures in the attached drawings, wherein:

- Fig. 1 shows a spinning machine provided with a detection apparatus according to this invention;
- Fig. 2 is a diagram of the spinning machine in Fig. 1;
- Fig. 3a and 3b show positive images of original neps

with corresponding pixel profile;

- Fig. 4 shows a set of positive images of synthetic neps.

[0019] For descriptive clarity, reference will be made below to a method and apparatus for detecting neps; however, it is understood that the invention is applicable to defect detection in general.

[0020] With reference to the attached figures, 1 collectively denotes a spinning machine of a spinning line for obtaining spools of yarn from bobbins of roving, having extension along a longitudinal axis X.

[0021] The spinning machine 1 comprises a frame 2 for supporting components, made in one or more parts arranged side by side, and a creel 4 supported by the frame 2.

[0022] The creel 4 comprises vertical posts 6 and a plurality of longitudinal cross members 8, supported by the posts 6 at a predetermined elevation. The crossbars 8 are intended to support a plurality of hanging bobbins of roving B.

[0023] Below the crossbars 8, i.e., downstream of the bobbins B, the spinning machine 1 comprises a drawing device 10, supported by the frame 2.

[0024] The drawing device 10 comprises a plurality of lower drawing cylinders 12a-12d, typically three or four in number, which are motorized, and extend longitudinally,

made in one piece or from multiple, structurally distinct, side-by-side and aligned segments.

[0025] The drawing device 10 further comprises a plurality of pressure arms 14 arranged side by side longitudinally. Each pressure arm carries upper idle pressure rollers 16.

[0026] Coupling with the pressure cylinders 12a-12d, the pressure rollers 16 form drawing pairs, through which the roving passes, which is drawn by the peripheral velocity of each drawing pair, increasing from upstream to downstream.

[0027] The spinning machine 1 further comprises a winding device 17 arranged below the drawing device 10, immediately downstream of the first drawing cylinder 12a.

[0028] The winding device 17 comprises a yarn guide assembly 18, comprising a support 20 connected to the frame 2, and a plurality of yarn guides 22, supported by the support 20 and arranged side by side longitudinally.

[0029] The winding device 17 further comprises a rail 23, located below the yarn guide assembly 18, i.e., downstream of the yarn guides 22. The rail 23 is supported by the frame 2 and is vertically translatable with reciprocating motion.

[0030] The winding device 17 further comprises a plurality of spindles 24 arranged side by side longitudinally along the rail 23, each rotatable about a respective vertical

axis.

[0031] In normal operation of the spinning machine 1, the roving wound in a predefined bobbin B travels a first path segment to pass into the drawing device 10, from which it comes out drawn; the drawn roving R travels a second path segment S2 between the drawing device and a respective spindle 24, passing through a respective yarn guide 22. The yarn obtained from the drawing and twisting of the roving is wound onto a tube fitted onto the spindle to form a spool of yarn.

[0032] According to this invention, a detection region 50 is defined, between the drawing device 10 and the winding device 17, crossed by the second path segment S2 of the drawn roving R.

[0033] The drawn roving passing through the detection region 50 is subjected to a process for defect detection, and in particular for the detection of tangles or knots, generally referred to as "neps."

[0034] The detection process comprises an acquisition step during which images of at least one segment R* of the roving R in transit through the detection region 50 are acquired.

[0035] For this purpose, the spinning machine 1 comprises acquisition means 60, e.g., digital, e.g., comprising a video camera, adapted to acquire images I of at least one

segment R* of the roving R in transit through the detection region 50.

[0036] Preferably, moreover, the spinning machine 1 comprises illumination means 62 adapted to illuminate, for example by means of a warm or cold light, or, in a variant embodiment, by infrared rays, at least one zone of the detection region 50 comprising the segment R* of the roving R.

[0037] The detection process further comprises a step of processing the images I acquired by said acquisition means 60, carried out by processing means 70.

[0038] Said processing means 70 are configured to detect neps by means of an adaptive or machine learning detection algorithm, in particular of the Haar-cascade type, preferably based on the Viola-Jones method. The latter is illustrated in the paper "Rapid object detection using a boosted cascade of simple features," presented at the Conference on Computer Vision and Pattern Recognition (2001) by Paul Viola and Michael Jones, whose teaching on the implementation of the algorithm is expressly incorporated here.

[0039] The learning of the detection algorithm is based on a set of positive images Ip, i.e., images in which the segment R* of drawn roving R has neps, and a set of negative images In, in which the segment R* of drawn

roving R does not have neps.

[0040] According to a first embodiment (referred to as "with original neps"), starting from images of a drawn roving for learning, e.g., acquired during normal use of a predefined spinning machine, and therefore depicting segments with neps and segments without neps, the positive images Ip of the positive image set are determined by means of processing a pixel profile for each image, wherein said pixel profile is obtained by adding the bright pixels on each row of the image and selecting as positive images those for which at least one peak of the pixel profile exceeds a threshold value, e.g. determined by means of a mean value and a standard deviation (Fig. 3a and 3b).

[0041] Preferably, moreover, the positive images are subjected to a further selection, eliminating the images in which the peak is given by single frayed hairs; said further selection is performed by means of an additional selection algorithm or manually.

[0042] According to a further embodiment (termed "with synthetic neps"), positive images Ip are digitally constructed and consist of images of semi-circles or semi-ellipses, preferably vertical (Fig. 4), e.g., differing from each other in the length of the minor axis and the major axis.

[0043] According to a still further embodiment (termed "hybrid"), positive images Ip comprise positive images with original neps and positive images with synthetic neps, i.e., combining the aforesaid two embodiments.

[0044] According to a further embodiment of the invention, said processing means are configured to detect neps using an adaptive or machine learning detection algorithm of the Convolutional Neural Networks (CNN) and/or Recurrent Neural Networks (RNN) type.

[0045] In the normal operation of the spinning machine, while the roving R is in transit through the detection area 50, the acquisition means 60 continuously acquire images I of a segment R* of the roving R.

[0046] Said images I are processed by the processing means 70 to detect the frequency of the neps and preferably their shape, thus classifying them by type, by means of the machine learning detection algorithm, in particular of the Haar-cascade type preferably based on the Viola-Jones method or by means of Convolutional Neural Networks (CNN) and/or Recurrent Neural Networks (RNN).

[0047] On the basis of these findings, as part of a method for managing the spinning machine or a spinning line comprising the spinning machine and machines upstream thereof, such as cards, combers, drawing frames and roving frames, the processing parameters of the spinning

machine, such as twisting of the yarn, drawing and/or pre-drawing of the roving, type, and weight of the ring, the hardness of the axle rubbers, cylinder gauge, pressure on the axles, and production speed are adjusted in order to improve roving quality, or the parameters are adjusted for the processes performed upstream of the spinning machine, such as twisting, drawing and/or pre-drawing, hardness of the axle rubbers, cylinder gauge, pressure on the axles, production speed in a roving frame, production speed and drawing assembly gauge in a drawing frame, percentage of rejects, number of strokes and drawing unit gauge in a combing machine, production speed, nep and trash removal in a card and in a blow room line, or maintenance work is carried out on the spinning machine or on the machines upstream thereof.

[0048] Innovatively, the apparatus and method for detecting defects in a spinning machine according to this invention meet the needs of the industry and overcome the aforesaid drawbacks.

[0049] Indeed, since the detection is carried out continuously on the roving being processed in the spinning machine, it is possible to intervene to modify the processing parameters on the spinning machine or on the machines upstream or to intervene with maintenance interventions in order to improve the quality of the

yarn.

[0050] Moreover, advantageously, this invention ensures good reliability of results, as it allows industrially acceptable discernment between major defects and other minor irregularities.

[0051] Furthermore, the tests carried out have shown a good correspondence between the readings obtained by means of the apparatus of this invention and the tests based on the testers normally used today as mentioned in the introduction.

[0052] Advantageously, moreover, the image processing according to the invention is very fast and enables continuous detection of defects and rapid action to improve production.

[0053] It is clear that a person skilled in the art, in order to satisfy contingent needs, may make modifications to the method and the apparatus described above, said modifications all being contained within the scope of protection as defined in the following claims.

CLAIMS

1. A method for detecting defects in a drawn roving (R) being processed in a spinning machine, comprising the step of acquiring images (I) of the drawn roving (R) in transit in a segment (Sr) of a path (S2) and the step of digitally processing said images (I) to detect said defects, wherein the image processing step (I) involves detecting defects using a machine learning detection algorithm, wherein the learning of the detection algorithm is based on a set of positive images (Ip) in which a depicted roving segment has defects, and a set of negative images (In) in which a depicted roving segment does not have said defects.

2. A method according to claim 1, wherein the processing step provides the step of detecting the frequency of the defects along the roving (R).

3. A method according to claim 1 or 2, wherein the processing step provides the step of detecting the type of defects.

4. A method according to any of the preceding claims, wherein, starting from images of a drawn roving for learning having segments with defects and segments without defects, the positive images (Ip) are determined by processing a pixel profile for each image, wherein said pixel profile is obtained by adding bright pixels on

each row of the image and selecting those for which at least one peak of the pixel profile exceeds a threshold value as positive images.

5. A method according to claim 4, wherein said threshold value is determined by means of an average value of the profile and a standard deviation.

6. A method according to claim 4 or 5, wherein said learning images of the roving are acquired during the normal use of a predefined spinning machine.

7. A method according to any one of claims 4 to 6, wherein the positive images are subjected to a further selection by eliminating the images in which the peak is given by individual pulled hairs.

8. A method according to claim 7, wherein said further selection is performed by means of a further selection algorithm.

9. A method according to claim 7, wherein said further selection is performed manually.

10. A method according to any of the preceding claims, wherein the positive images (Ip) are digitally built and formed by images of preferably vertical semi-circles or semi-ellipses, for example different from one another in length of the minor axis and of the major axis.

11. A method according to any of claims 1 to 9, wherein

- a part of the positive images (Ip) is obtained by means

of a machine learning detection algorithm; and

- a remaining part of the positive images (Ip) is obtained by means of digital construction.

12. A method according to any of the preceding claims, wherein the detection algorithm is of the Haar-cascade type.

13. A method according to claim 12, wherein the detection algorithm of the Haar-cascade type is based on the Viola-Jones method.

14. A method according to any of claims 1 to 11, wherein the algorithm is of the Convolutional Neural Networks (CNN) and/or Recurrent Neural Networks (RNN) type.

15. A method for managing a spinning machine (1) of a spinning line, comprising:

- a method for detecting defects in a drawn roving (R) according to any of the preceding claims, and

- a successive step of varying processing parameters of the spinning machine or performing maintenance operations on said spinning machine.

16. A method for managing a spinning line comprising a spinning machine (1) and machines for textile processing upstream of the spinning machine, comprising

- a method for detecting defects on the spinning machine (1) according to any of claims 1 to 14, and

- a successive step of varying processing parameters of

at least one of said machines upstream of the spinning machine or performing maintenance operations on at least one of said machines upstream of the spinning machine.

17. An apparatus for detecting defects in a drawn roving (R) being processed in a spinning machine, comprising:

- acquisition means (60) adapted to acquire images (I) of the drawn roving (R) from a detection area (50) located between a drawing device (10) and a winding device (17) of the spinning machine, said detection area (50) being crossed by a segment (Sr) of a path (S2) of the roving (R);

- processing means (70) operatively connected to the acquisition means for digitally processing said images (I) and detecting the defects;

said processing means (70) being configured to detect the defects by means of a machine learning detection algorithm, wherein the learning of the detection algorithm is based on a set of positive images (Ip) in which a represented segment of roving has defects, and a set of negative images (In), in which a represented segment of drawn roving does not have said defects.

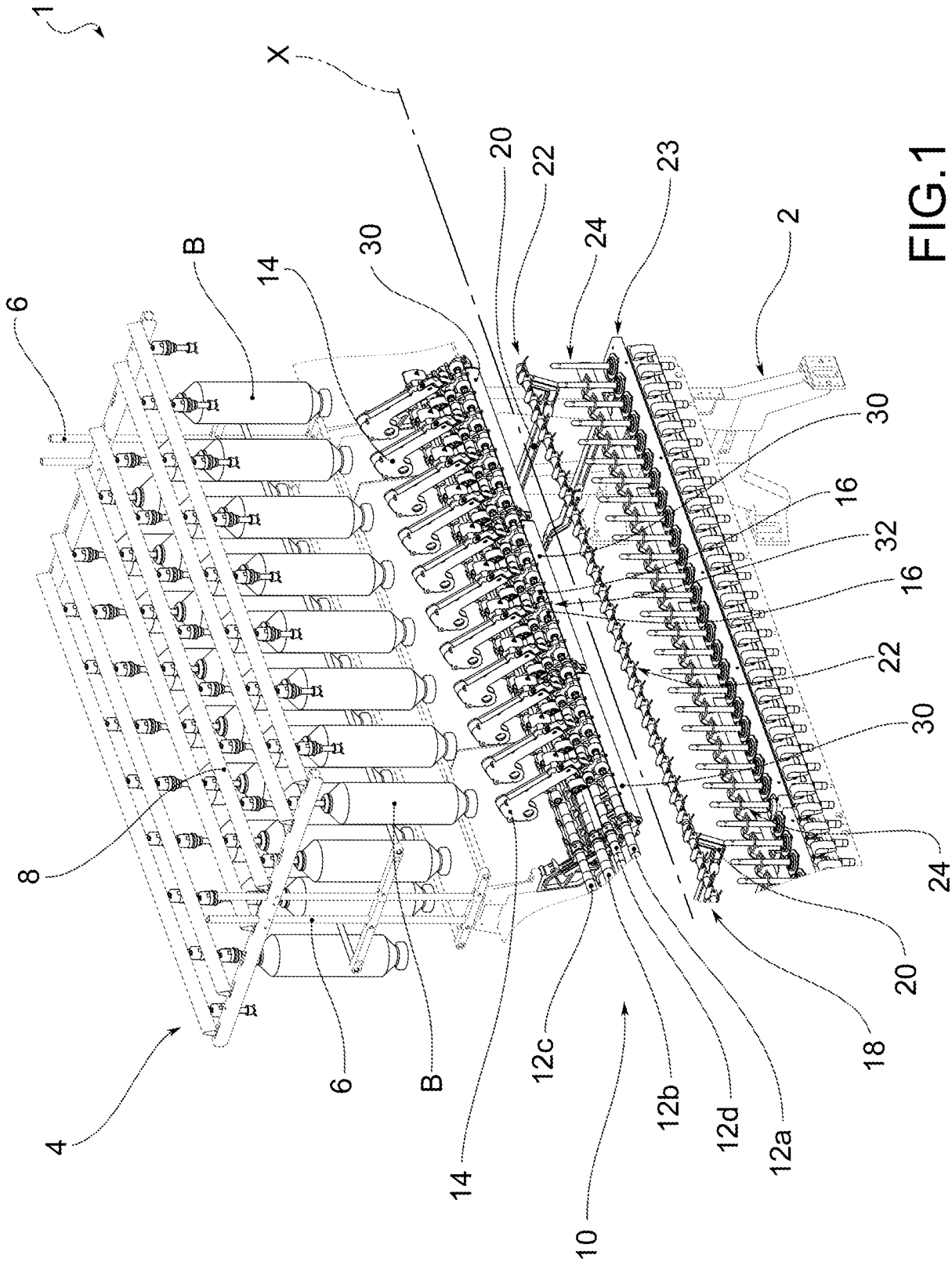
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FIG.1

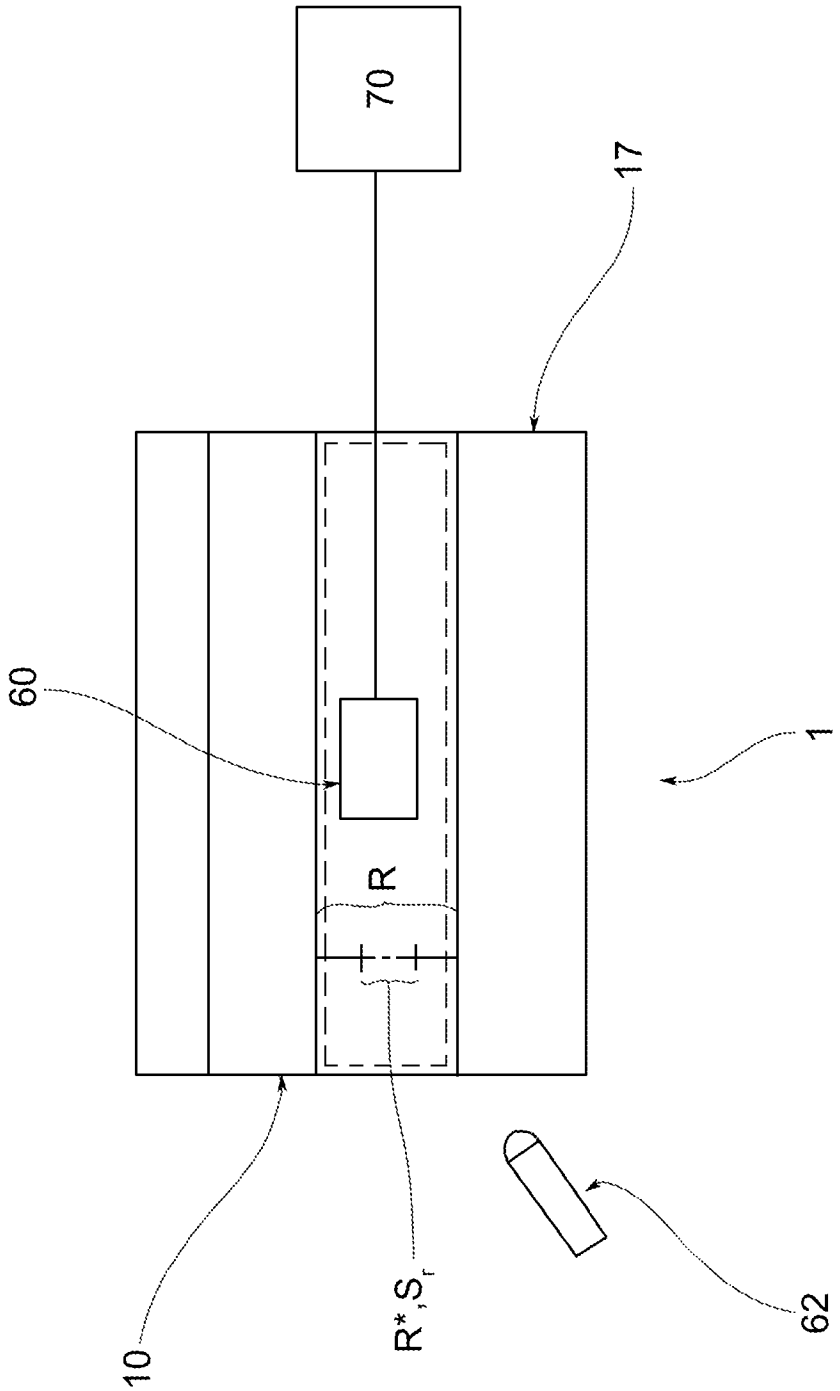

FIG.2

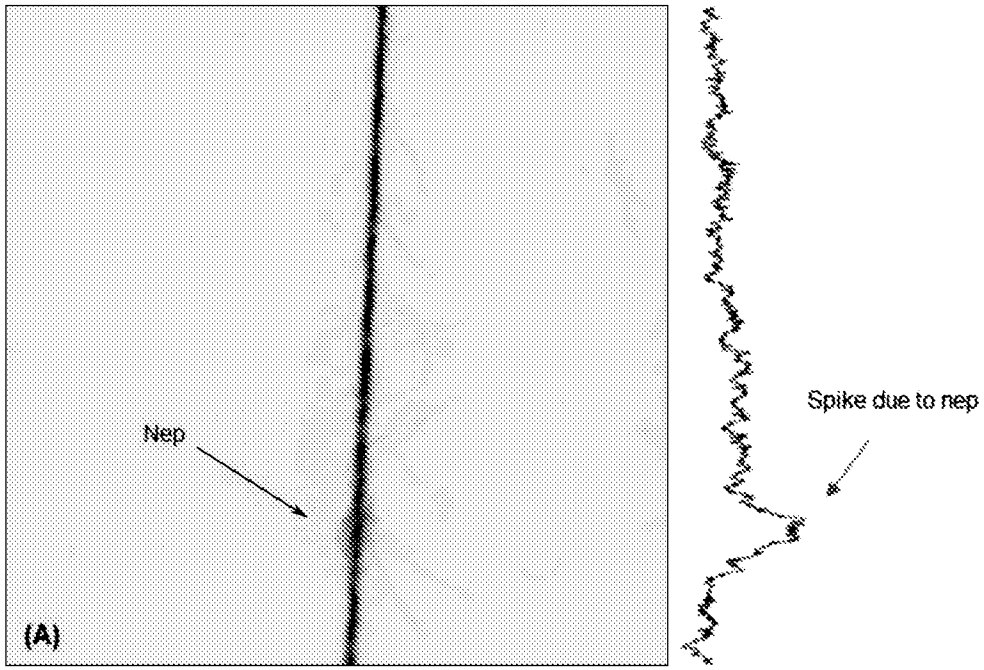

FIG.3a

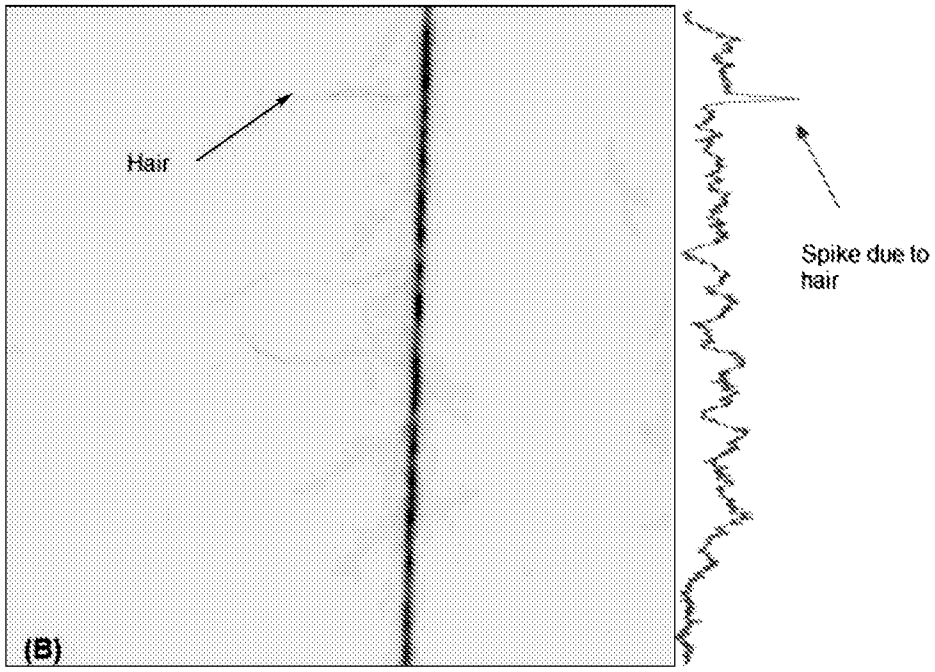

FIG.3b

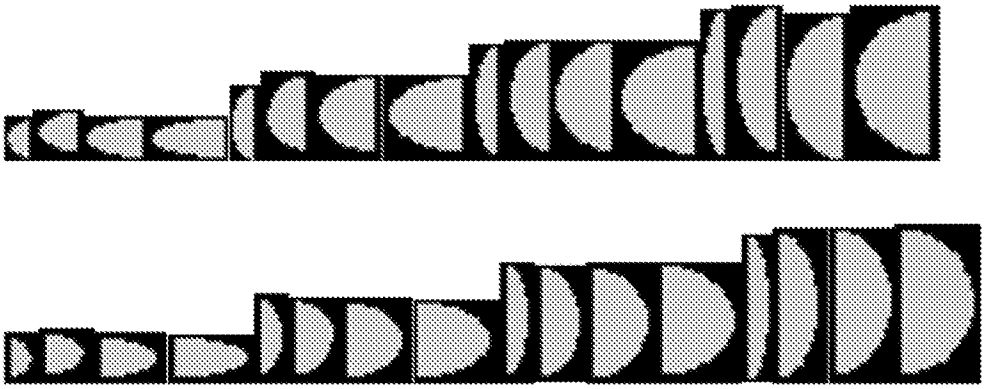

FIG.4

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2021/059569

A. CLASSIFICATION OF SUBJECT MATTER
INV. D01H13/32 G01N21/89 G01N33/36
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
D01H G01N G01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 111 235 709 A (UNIV NATIONAL DONG HWA) 5 June 2020 (2020-06-05) cited in the application paragraph [0017] - paragraph [0025] paragraph [0032] paragraph [0042] - paragraph [0043] figures 2, 3, 5, 6	1-17
A	CN 109 389 583 A (UNIV NATIONAL DONG HWA) 26 February 2019 (2019-02-26) cited in the application paragraph [0068] - paragraph [0088]; figures 1-2	1-17

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 November 2021	09/12/2021

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2021/059569

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 105 386 174 A (UNIV JIANGNAN) 9 March 2016 (2016-03-09) cited in the application paragraph [0018] - paragraph [0023]; figures 1-2	1-17

A	Viola Paul ET AL: "ACCEPTED CONFERENCE ON COMPUTER VISION AND PATTERN RECOGNITION 2001 Rapid Object Detection using a Boosted Cascade of Simple Features", , 14 December 2001 (2001-12-14), XP055823865, Retrieved from the Internet: URL:https://www.cs.cmu.edu/~efros/courses/LBMV07/Papers/viola-cvpr-01.pdf [retrieved on 2021-07-13] cited in the application the whole document	1-17

A	EP 1 621 872 A2 (PREMIER EVOLVICS PVT LTD [IN]) 1 February 2006 (2006-02-01) paragraph [0073] - paragraph [0075]; figure 4	1-17

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2021/059569

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 111235709 A	05-06-2020	NONE	
CN 109389583 A	26-02-2019	NONE	
CN 105386174 A	09-03-2016	NONE	
EP 1621872 A2	01-02-2006	AU 2003200850 A1	10-08-2004
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		EP 1581807 A2	05-10-2005
		EP 1621872 A2	01-02-2006
		EP 1624302 A2	08-02-2006
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