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(54) Sorting apparatus and method

(57) A sorting apparatus for and method of sorting particulate product within a product stream, the apparatus comprising: a delivery device for delivering a product stream of product particles to fall in a vertical axis; a detection system for detecting individual product particles across the product stream at a plurality of detection locations in the vertical axis and determining individual velocities, optionally either vertical or vertical and horizontal, of the individual product particles based on detection of the individual product particles at the plurality of detection locations; and an ejector system for ejecting product particles identified as being unacceptable from the product stream at an ejection location below the detection locations, wherein the ejector system is actuated in response to the determined individual velocities of the individual product particles.

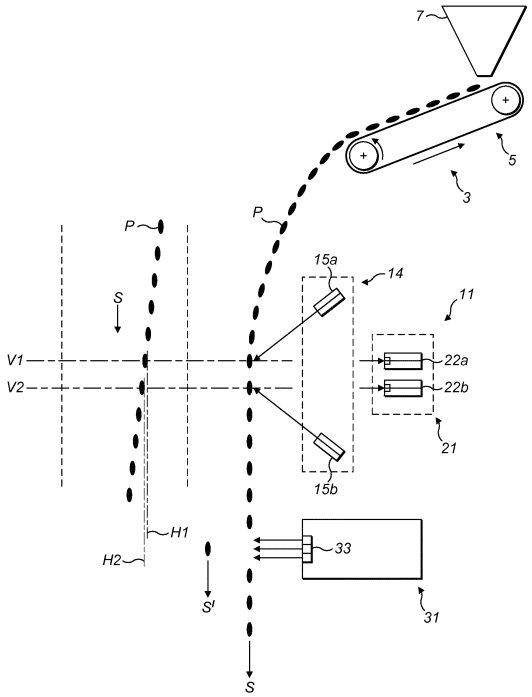

FIG. 1

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Description

[0001] The present invention relates to a sorting apparatus for and method of sorting particulate product, especially to high-throughput sorting of a product stream where individual particulate products within the product stream can exhibit a significant velocity distribution.

[0002] In a conventional machine, a product stream, which contains acceptable and defective particles, is viewed at a given viewing point in the vertical axis, following acceleration due to gravity, typically down a feed chute which provides a mono layer of product particles, and product particles which are identified as being defective are removed from the product stream at an ejection point by an ejection system, typically by the application of a jet of air, at a location vertically lower than the viewing point. In this conventional machine, the ejection system is operated based on a determination of mean velocity of the product particles.

[0003] In machine development, especially of higher-throughput machines, such as in the sorting of grains, which provide an external force to the product stream, such as by air knives or conveyors, the present inventors have recognized that there is an increased uncertainty in the spatial location of particles in relation to the ejection point, given an increase of the variance in the velocity of the product particles within the product stream, arising, for example, due to drag, friction and rotation. In conventional machines, this increased uncertainty can be accommodated by operating the ejection system for a longer period in order to ensure that a defective particle will be removed from the product stream, but this mode of operation results in an increase in the number of acceptable product particles which are unnecessarily removed from the product stream.

[0004] The present inventors have also recognized that the present invention has application to products of a type which have a high drag coefficient relative to mass, for example, potato crisps, leaves and petals, such that the terminal velocity is less than or near to the typical throughput velocity, causing an inherent variation in velocity distribution at the viewing point. Furthermore, at the relatively low velocities in the vertical axis observed in these product types, the velocity in the horizontal axis has been observed to have a greater absolute effect on the location of the product when reaching the ejection point and measurement of the horizontal velocity allows for improved assignation of the ejector or ejectors for any given particle.

[0005] It is an aim of the present invention to provide a sorting apparatus and method which allows for the improved sorting of product streams which exhibit significant variance in velocity distribution, especially in high-throughput product flows and for products which have a high drag coefficient in relation to mass, whereby the fraction of unacceptable product particles removed from the product stream is above a required threshold and the fraction of acceptable product particles removed from the product stream is below a required threshold.

[0006] In this way, in removing unacceptable product particles from a product stream, the number of acceptable product particles which are removed from the product stream can be minimized.

[0007] In one aspect the present invention provides a sorting apparatus for sorting particulate product within a product stream, the apparatus comprising: a delivery device for delivering a product stream of product particles to fall in a vertical axis; a detection system for detecting individual product particles across the product stream at a plurality of detection locations in the vertical axis and determining individual velocities, optionally either vertical or vertical and horizontal, of the individual product particles based on detection of the individual product particles at the plurality of detection locations; and an ejector system for ejecting product particles identified as being unacceptable from the product stream at an ejection location below the detection locations, wherein the ejector system is actuated in response to the determined individual velocities of the individual product particles.

[0008] In one embodiment the delivery device is configured to impart a force to the product particles which is additional to gravitational force, whereby the product stream is delivered at a higher velocity than can be achieved by gravitational flow alone.

[0009] In one embodiment the delivery device comprises (1) a conveyor which conveys the particles and is inclined to the horizontal to impart a force, in addition to gravitational force, to the product particles in the vertical axis, or (2) a chute which is inclined to the horizontal and a force-imparting mechanism, optionally an air knife, which acts to impart a force, in addition to gravitational force, to the product particles in the vertical axis.

[0010] In one embodiment the detection system comprises a plurality of line-scan cameras, which image a width of the product stream at respective ones of the plurality of detection locations in the vertical axis, whereby product particles when passing each of the detection locations are detected by elements of the line-scan cameras.

[0011] In one embodiment the detection system comprises a multiple line-scan camera or an area-scan camera, which images a width of the product stream at respective ones of the plurality of detection locations in the vertical axis, whereby product particles when passing each of the detection locations are detected by elements of the line-scan cameras.

[0012] In one embodiment the detection system detects product particles at first and second detection locations in the vertical axis, and measures a time interval between each individual product particle passing the first and second detection locations, from which vertical velocities of the individual product particles are determined, and optionally the detection system measures horizontal displacement of each individual product particle from changes in horizontal positions in passing between the first and second detection locations, and from these dis-

placements, horizontal velocities of the individual product particles are determined.

[0013] In one embodiment the ejector system comprises a horizontally-extending array of ejector nozzles which are actuatable to provide air pulses to eject unacceptable product particles from the product stream, and the timing of the air pulses to the ejector nozzles is responsive to the determined vertical velocities of the individual product particles, optionally ones of the ejector nozzles in the horizontal array are selectively operated in dependence upon the determined horizontal velocities of the individual product particles.

[0014] In another aspect the present invention provides a method of sorting particulate product within a product stream, the method comprising the steps of: delivering a product stream of product particles to fall in a vertical axis; detecting individual product particles across the product stream at a plurality of detection locations in the vertical axis; determining velocities, optionally vertical or both vertical and horizontal, of the individual product particles based on detection of the individual product particles at the plurality of detection locations; and ejecting product particles identified as being unacceptable from the product stream at an ejection location below the detection locations using an ejector system, wherein the ejector system is actuated in response to the determined individual velocities of individual product particles.

[0015] In one embodiment the method further comprises the step of: imparting a force to the product particles which is additional to gravitational force, whereby the product stream is delivered at a higher velocity than can be achieved by gravitational flow alone.

[0016] In one embodiment the force-imparting step comprises (1) conveying the product particles on a conveyor which is inclined to the horizontal to impart a force, in addition to gravitational force, to the product particles in the vertical axis, or (2) delivering the product particles on a chute and operating a force-imparting mechanism, optionally an air knife, which acts to impart a force, in addition to gravitational force, to the product particles in the vertical axis.

[0017] In one embodiment the detecting step utilizes a plurality of line-scan cameras, which image a width of the product stream at respective ones of the plurality of detection locations in the vertical axis, whereby product particles when passing each of the detection locations are detected by elements of the line-scan cameras.

[0018] In one embodiment the detecting step utilizes a multiple line-scan camera or an area-scan camera, which images a width of the product stream at respective ones of the plurality of detection locations in the vertical axis, whereby product particles when passing each of the detection locations are detected by elements of the line-scan cameras.

[0019] In one embodiment, in the detecting step, product particles are detected at first and second detection locations in the vertical axis, a time interval is measured between each individual product particle passing the first and second detection locations, and vertical velocities of the individual product particles are determined, and optionally horizontal displacement of each individual product particle is measured from changes in horizontal positions in passing between the first and second detection locations, and from these displacements, horizontal velocities of the individual product particles are determined.

[0020] In one embodiment the ejector system comprises a horizontally-extending array of ejector nozzles which are actuatable to provide air pulses to eject unacceptable product particles from the product stream, and the ejecting step comprises operating the ejector nozzles to provide air pulses with a timing responsive to the determined individual vertical velocities of the individual product particles, and optionally the ejecting step comprises operating ones of the ejector nozzles in the horizontal array in dependence upon the determined horizontal velocities of the individual product particles.

[0021] In one embodiment the particulate product comprises foodstuffs or other particulate commodities, including grains, potato chips, leaves and petals.

[0022] Preferred embodiments of the present invention will now be described hereinbelow by way of example only with reference to the accompanying drawings, in which:

Figure 1 illustrates a sorting apparatus in accordance with one embodiment of the present invention;

Figure 2 illustrates a sorting apparatus as a modification of the sorting apparatus of Figure 1; and

Figure 3 illustrates a sorting apparatus as another modification of the sorting apparatus of Figure 1.

[0023] The sorting apparatus comprises a delivery device 3 for delivering a product stream S of product particles P, here a particulate material, such as foodstuffs or other particulate commodities.

[0024] In this embodiment the product particles P are grains, here unhulled grains, such as of paddy or rough rice.

[0025] In an alternative embodiment the product particles P could be of a type which have a high drag coefficient relative to mass, for example, potato crisps, leaves and petals.

[0026] In this embodiment the delivery device 3 comprises a conveyor 5, here fed from a hopper 7, which is inclined from the horizontal such as to impart a force, in addition to gravitational force, to the product particles P and thereby provide a higher-throughput product stream S than achieved by a gravitational flow alone.

[0027] In another embodiment, as illustrated in Figure 2, the delivery device 3 could comprise a chute 8 which is inclined from the horizontal and a force-imparting mechanism 9, such as an air knife, acts to impart an additional force to the product particles P as being delivered from the chute 8.

[0028] The sorting apparatus further comprises a detection system 11 for detecting individual product particles P across the product stream S at a plurality of locations in a vertical axis, here at first and second vertical locations V1, V2. For ease of understanding, Figure 1 illustrates a time-lapse path of a single product particle P in the product stream S, both in side and front elevation. As will be seen, the product particle P has both a horizontal velocity and a vertical velocity, with the product particle P moving laterally while falling.

[0029] In this embodiment the detection system 11 measures the time interval between each individual product particle P passing the first and second vertical locations V1, V2. From these time intervals, the vertical velocities of the individual product particles P are determined.

[0030] In this embodiment the detection system 11 further measures the horizontal displacement of each individual product particle P from the change in the horizontal positions H1, H2 in passing between the first and second vertical locations V1, V2. From these displacements, the horizontal velocities of the individual product particles P are determined.

[0031] With this configuration, the apparatus allows for operation of an ejection system 31 in response to the individual measured velocities, both vertical and horizontal, as will described in more detail hereinbelow. In an alternative embodiment the detection system 11 could determine only the vertical velocities of the product particles, and provide for operation of the ejection system 31 in response only to the individual measured vertical velocities.

[0032] In this embodiment a product particle P is detected by identifying an edge of the product particle P, here a leading or trailing edge for determination of vertical velocity and a lateral edge for determination of horizontal velocity. In an alternative embodiment the locations of the product particles P could be identified by any means of feature recognition, such as shape or pattern recognition.

[0033] The detection system 11 comprises an illumination unit 14, in this embodiment comprising first and second illumination sources 15a, b, here providing elongate illumination beams, which illuminate narrow, elongate lines across a width of the product stream 5 at respective ones of the first and second vertical locations V1, V2.

[0034] In an alternative embodiment the illumination unit 14 could comprise a single illumination source 15, which illuminates both the first and second vertical locations V1, V2.

[0035] In this embodiment the illumination sources 15a, b provide visible light, but could provide any of X-rays, including near X-rays, UV, or infrared, including near infrared, microwave or terahertz radiation.

[0036] In one embodiment the illumination sources 15a, b each comprise a laser, which provides a laser beam, and illumination optics which provide a fixed elongate line of illumination.

[0037] The detection system 11 further comprises a detection unit 21, in this embodiment comprising first and second line-scan cameras 22a, b, which image respective ones of the first and second vertical locations V1, V2 across the width of the product stream S, whereby product particles P when passing each of the first and second vertical locations V1, V2 are detected by elements of the line-scan cameras 22a, b.

[0038] In this embodiment the line-scan cameras 22a, b comprise CCD or CMOS sensors.

[0039] In this embodiment the line-scan cameras 22a, b each comprise one-dimensional or linear arrays, for example, 1024x1 pixels.

[0040] In an alternative embodiment, as illustrated in Figure 3, the detection unit 21 could comprise a single multiple line-scan camera or area-scan camera 22 which detects both the first and second vertical locations V1, V2, with separate lines of the camera 22 being used to detect the separate vertical locations V1, V2. An area-scan camera 22 provides an advantage, in allowing for greater spatial resolution, in that the detection lines are not adjacent, but can have a significant spacing. In this embodiment the area-scan camera 22 could comprise a two-dimensional array, for example, 1024x1024 pixels.

[0041] In one embodiment more than two vertical locations V1, V2, ..., Vn could be imaged, which allows for averaging in the determination of the vertical velocity of each product particle P. In this embodiment the detection system 11 could also measure the horizontal position of each product particle P at the more than two vertical locations V1, V2, ..., Vn, which allows for averaging in the determination of the horizontal velocity of each product particle P.

[0042] The sorting apparatus further comprises an ejector system 31, in this embodiment comprising a horizontally-extending array of ejector nozzles 33, with ones of the ejector nozzles 33 in the horizontal array being selectively operated in dependence upon the determined horizontal velocities of the individual product particles P and the timing of the air pulses to the ejector nozzles 33 being responsive to determined vertical velocities of the individual product particles P, such as to eject unacceptable product particles P from the product stream S into a separate product stream S', which is typically a waste flow.

[0043] Finally, it will be understood that the present invention has been described in relation to its preferred embodiments and can be modified in many different ways without departing from the scope of the invention as defined by the appended claims.

Claims

1. A sorting apparatus for sorting particulate product within a product stream, the apparatus comprising:

a delivery device for delivering a product stream of product particles to fall in a vertical axis;
a detection system for detecting individual product particles across the product stream at a plurality of detection locations in the vertical axis and determining individual velocities, optionally either vertical or
vertical and horizontal, of the individual product particles based on detection of the individual product particles at the plurality of detection locations; and
an ejector system for ejecting product particles identified as being unacceptable from the product stream at an ejection location below the detection locations, wherein the ejector system is actuated in response to the determined individual velocities of the individual product particles.

2. The apparatus of claim 1, wherein the delivery device is configured to impart a force to the product particles which is additional to gravitational force, whereby the product stream is delivered at a higher velocity than can be achieved by gravitational flow alone.

3. The apparatus of claim 2, wherein the delivery device comprises (1) a conveyor which conveys the particles and is inclined to the horizontal to impart a force, in addition to gravitational force, to the product particles in the vertical axis, or (2) a chute which is inclined to the horizontal and a force-imparting mechanism, optionally an air knife, which acts to impart a force, in addition to gravitational force, to the product particles in the vertical axis.

4. The apparatus of any of claims 1 to 3, wherein the detection system comprises a plurality of line-scan cameras, which image a width of the product stream at respective ones of the plurality of detection locations in the vertical axis, whereby product particles when passing each of the detection locations are detected by elements of the line-scan cameras.

5. The apparatus of any of claims 1 to 3, wherein the detection system comprises a multiple line-scan camera or an area-scan camera, which images a width of the product stream at respective ones of the plurality of detection locations in the vertical axis, whereby product particles when passing each of the detection locations are detected by elements of the line-scan cameras.

6. The apparatus of any of claims 1 to 5, wherein the detection system detects product particles at first and second detection locations in the vertical axis, and measures a time interval between each individual product particle passing the first and second detection locations, from which vertical velocities of the individual product particles are determined, and optionally the detection system measures horizontal displacement of each individual product particle from changes in horizontal positions in passing between the first and second detection locations, and from these displacements, horizontal velocities of the individual product particles are determined.

7. The apparatus of any of claims 1 to 6, wherein the ejector system comprises a horizontally-extending array of ejector nozzles which are actuatable to provide air pulses to eject unacceptable product particles from the product stream, and the timing of the air pulses to the ejector nozzles is responsive to the determined vertical velocities of the individual product particles, optionally ones of the ejector nozzles in the horizontal array are selectively operated in dependence upon the determined horizontal velocities of the individual product particles.

8. A method of sorting particulate product within a product stream, the method comprising the steps of:

delivering a product stream of product particles to fall in a vertical axis;
detecting individual product particles across the product stream at a plurality of detection locations in the vertical axis;
determining velocities, optionally vertical or both vertical and horizontal, of the individual product particles based on detection of the individual product particles at the plurality of detection locations; and
ejecting product particles identified as being unacceptable from the product stream at an ejection location below the detection locations using an ejector system, wherein the ejector system is actuated in response to the determined individual velocities of individual product particles.

9. The method of claim 8, further comprising the step of:

imparting a force to the product particles which is additional to gravitational force, whereby the product stream is delivered at a higher velocity than can be achieved by gravitational flow alone.

10. The method of claim 9, wherein the force-imparting step comprises (1) conveying the product particles on a conveyor which is inclined to the horizontal to impart a force, in addition to gravitational force, to the product particles in the vertical axis, or (2) delivering the product particles on a chute and operating a force-imparting mechanism, optionally an air knife, which acts to impart a force, in addition to gravitational force, to the product particles in the vertical axis.

11. The method of any of claims 8 to 10, wherein the

detecting step utilizes a plurality of line-scan cameras, which image a width of the product stream at respective ones of the plurality of detection locations in the vertical axis, whereby product particles when passing each of the detection locations are detected by elements of the line-scan cameras.

12. The method of any of claims 8 to 10, wherein the detecting step utilizes a multiple line-scan camera or an area-scan camera, which images a width of the product stream at respective ones of the plurality of detection locations in the vertical axis, whereby product particles when passing each of the detection locations are detected by elements of the line-scan cameras.

13. The method of any of claims 8 to 12, wherein, in the detecting step, product particles are detected at first and second detection locations in the vertical axis, a time interval is measured between each individual product particle passing the first and second detection locations, and vertical velocities of the individual product particles are determined, and optionally horizontal displacement of each individual product particle is measured from changes in horizontal positions in passing between the first and second detection locations, and from these displacements, horizontal velocities of the individual product particles are determined.

14. The method of any of claims 8 to 13, wherein the ejector system comprises a horizontally-extending array of ejector nozzles which are actuatable to provide air pulses to eject unacceptable product particles from the product stream, and the ejecting step comprises operating the ejector nozzles to provide air pulses with a timing responsive to the determined individual vertical velocities of the individual product particles, and optionally the ejecting step comprises operating ones of the ejector nozzles in the horizontal array in dependence upon the determined horizontal velocities of the individual product particles.

15. The apparatus or method of any of claims 1 to 14, wherein the particulate product comprises foodstuffs or other particulate commodities, including grains, potato chips, leaves and petals.

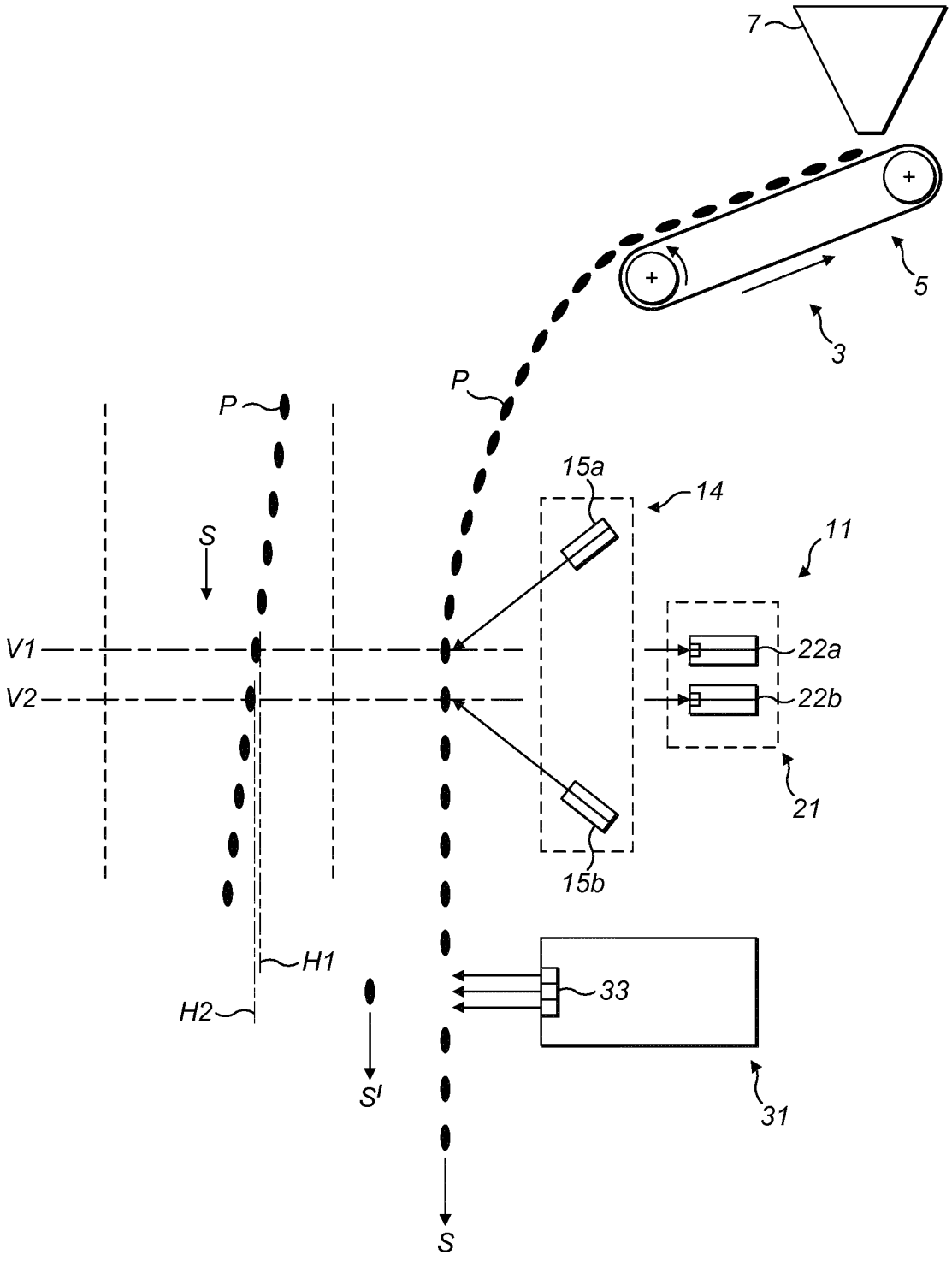

FIG. 1

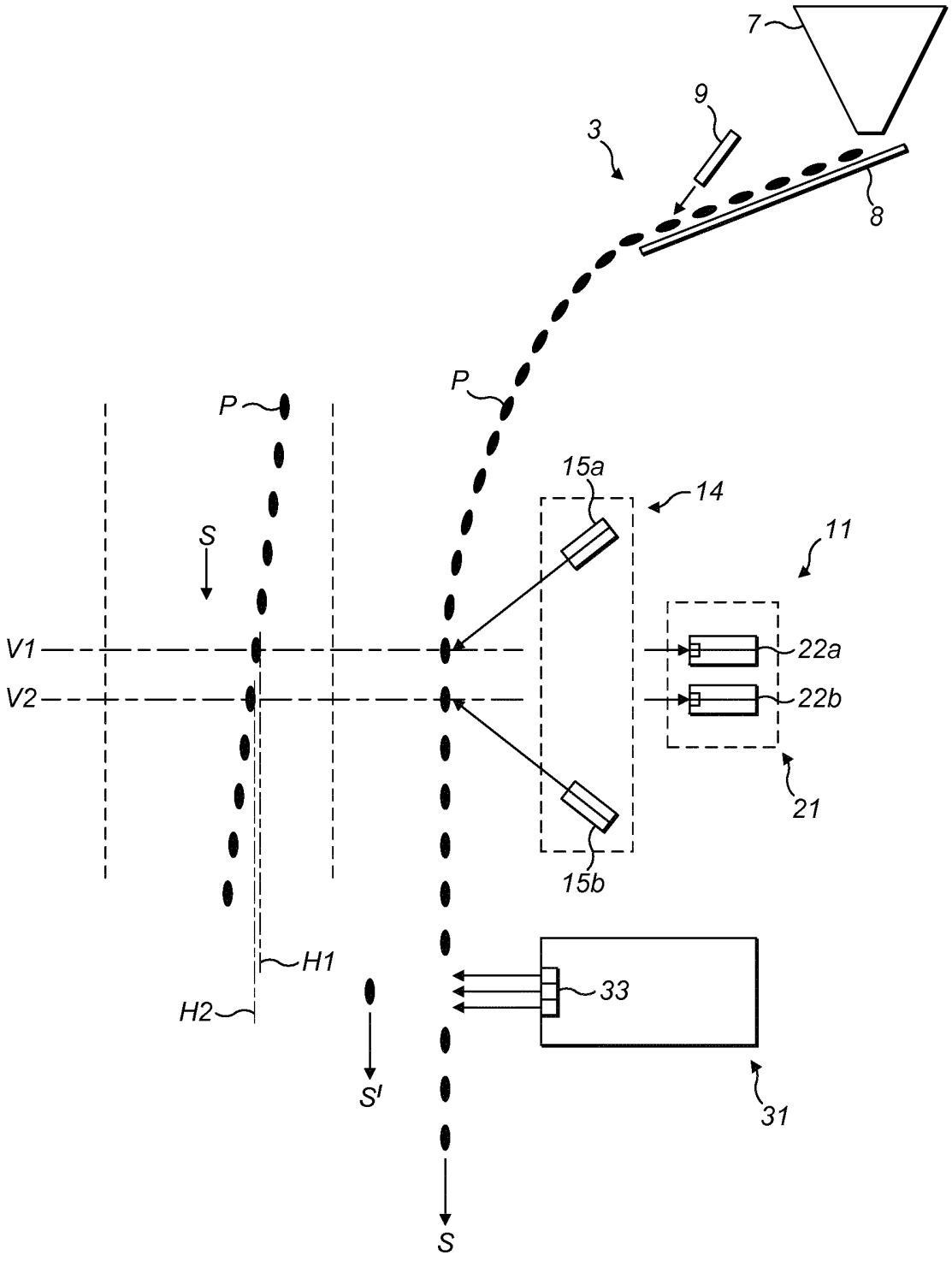

FIG. 2

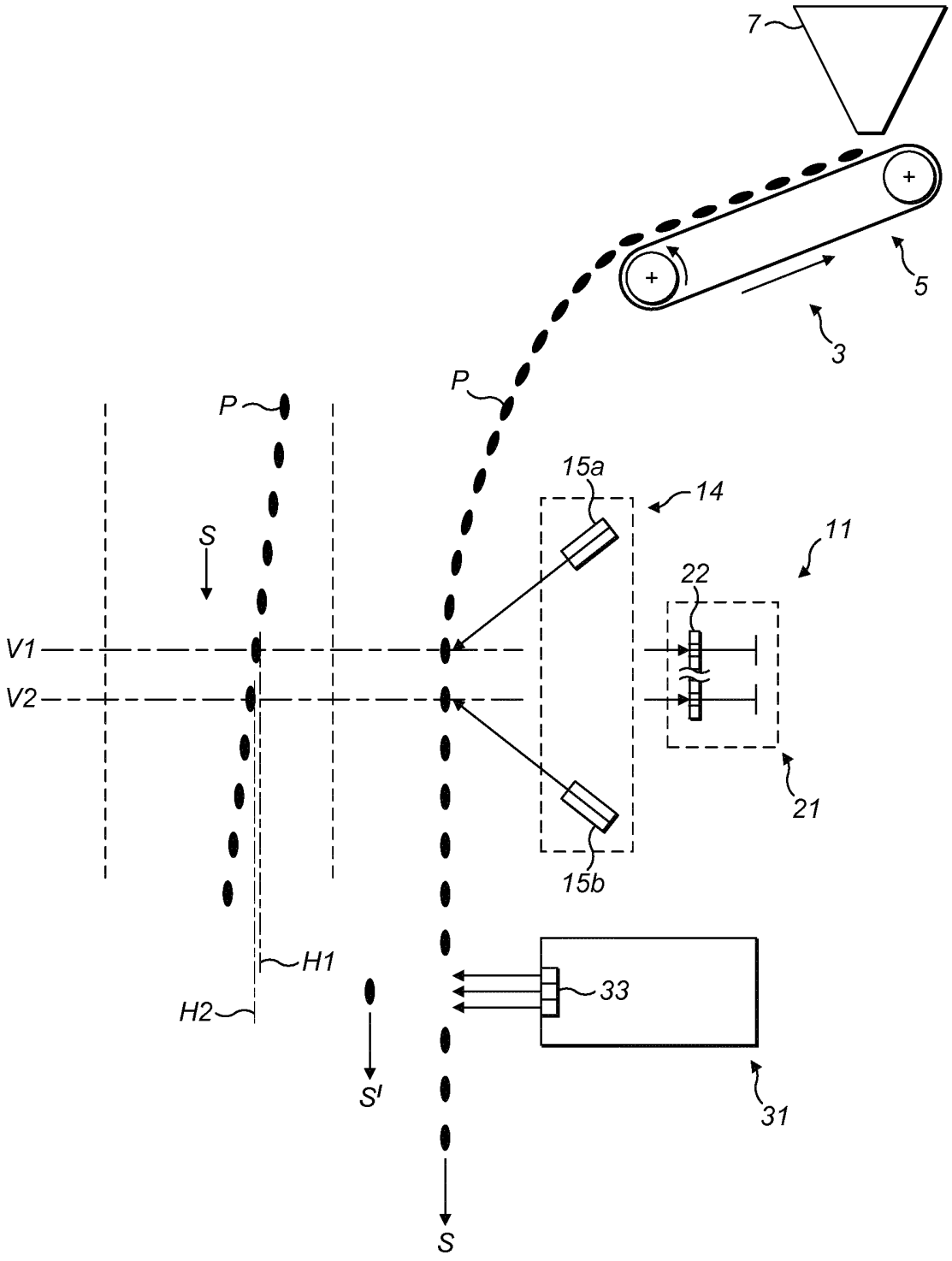

FIG. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 14 15 5092

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	US 4 365 719 A (KELLY LEONARD) 28 December 1982 (1982-12-28) * column 7, line 6 - line 32 * -----	1-15	INV. B07C5/342 B07C5/36
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	29 July 2014	Wich, Roland

CATEGORY OF CITED DOCUMENTS

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