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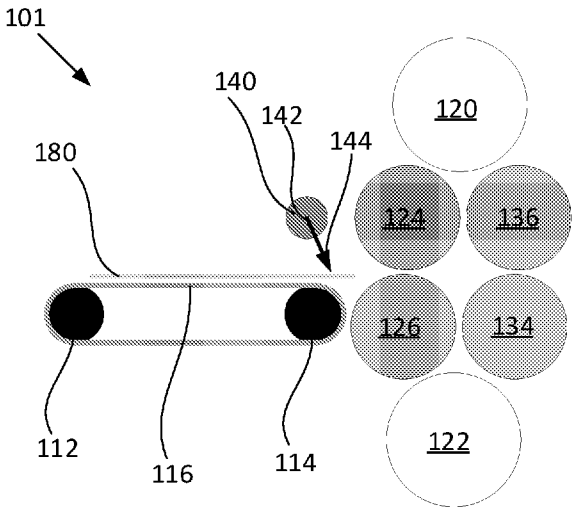

FIG. 6

(57) **Abstract:** The present invention relates to a contact cleaning apparatus for a sheet substrate (80) having a curved leading edge (82). The contact cleaning apparatus comprises an elastomeric cleaning roller (24) and an air supply manifold (40) configured and arranged to direct air towards a contact zone on the elastomeric roller; and a conveyor (16) for carrying a sheet substrate to be cleaned towards the elastomeric cleaning roller, wherein the air supply manifold configured and arranged to a direct stream of air onto a leading edge of the curved sheet and/or onto the contact zone of the elastomeric cleaning roller such that the sheet is flattened at the point of contact with the cleaning roller. A contact cleaning apparatus for a sheet substrate having a curved leading edge comprising a flattening means is also disclosed. The flattening means is disposed proximate a first conveyor and is configured to operably engage the curved leading edge of the sheet substrate such that the curved leading edge of the sheet substrate is flattened at a point of contact with the elastomeric cleaning roller.

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CONTACT CLEANING APPARATUS

[0001] The present application claims the benefit of United Kingdom Patent Application No. GB2002942.7, filed March 1, 2020, and claims the benefit of United Kingdom Patent Application No. GB2101993.0, filed February 12, 2021. The entireties of United Kingdom Patent Application No. GB2002942.7 and United Kingdom Patent Application No. GB2101993.0 are expressly incorporated herein by reference.

Field

[0002] The present invention relates to a contact cleaning apparatus for a sheet substrate having a curved leading edge. In particular, but not exclusively, the invention relates to a contact cleaning apparatus for a sheet substrate having a curved leading edge wherein the apparatus comprises flattening means operably engage the curved leading edge of the sheet substrate. The invention also relates to an air supply manifold directing air onto the surface of the sheet substrate at a curved leading edge of the sheet and/or onto the elastomeric cleaning roller prior to the arrival of the leading edge of the sheet substrate.

Background

[0003] Contact cleaning is used to clean the surface of substrates or sheets. Once the substrate is cleaned, they are used in a variety of sophisticated processes such as in the manufacture of electronics, photovoltaics and flat panel displays. Typically, a contact cleaning apparatus consists of a rubber or elastomeric cleaning roller used to remove contaminating particles from a substrate surface, and an adhesive roll which is used to remove the contaminating particles from the cleaning roller.

[0004] In operation, a contact cleaning roller contacts at least an upper surface of the substrate, removing debris by means of adhesion removal mechanisms such as van der Waals force and adhesion forces. The inherent properties of the material used to form the contact cleaning roller attracts the debris and causes the debris to stick to the surface of the contact cleaning roller. The contact cleaning roller pulls the contaminating particles away from the substrate surface in this manner due to attractive van der Waals forces between the contaminating particles and the roller. Consequently, existing contact cleaning rollers may ensure effectiveness in removing the contaminating particles by maximising contact with the substrate surface.

[0005] Contact cleaning apparatus for thin film sheet technology such as for example copper foil, or thin film polymer requires an elastomeric cleaning roller to be driven at speed and subsequently cleaned by an adhesive roll located adjacent to the elastomeric cleaning roller. As used herein, such thin film sheet technology is known as a sheet substrate.

[0006] As a new thin sheet substrate leading edge arrives at the elastomeric cleaning roller, it is typical for the sheet substrate to have a curved leading edge. The curved leading edge risks colliding with the elastomeric cleaning roller causing crumpling of the sheet substrate, damaging a portion of the sheet substrate, thereby rendering part of the sheet substrate unusable. Damage to the leading edge reduces process efficiency and risks failure of or damage to the machine.

[0007] In other scenarios, the sheet substrate wraps around the elastomeric cleaning roller and the machine must be stopped in order to cleanse the roller of sheet substrate and restart the machinery. Again, the efficiency of the cleaning process is significantly impaired.

[0008] In certain situations, a sheet substrate is stiff due to its relative thickness or its inherent material properties. Additionally, or alternatively, a sheet substrate has curvature, for example in multiple directions, which reinforces the curved leading edge. In these ways, a curved leading edge of a sheet substrate will resist deformation, increasing the risk of failure or of damage to the machine.

[0009] It is an aim of the present invention to mitigate some of the aforementioned disadvantages.

Summary of the Invention

[0010] In accordance with the present invention there is provided a contact cleaning apparatus according to the appended claims.

[0011] In a first aspect of the invention, a contact cleaning apparatus for a sheet substrate has a curved leading edge including:

an elastomeric cleaning roller and a first conveyor for carrying the sheet substrate to be cleaned towards said elastomeric cleaning roller, wherein said elastomeric cleaning roller includes a contact zone arranged to receivingly engage the sheet substrate from said first conveyor, and

a flattening means disposed proximate said first conveyor, wherein said flattening means is configured to operably engage the curved leading edge of the sheet

substrate such that the curved leading edge of the sheet substrate is flattened at a point of contact with the elastomeric cleaning roller.

[0012] In certain embodiments, said flattening means includes a guide, opposingly arranged with said first conveyor, and configured to contactingly engage the curved leading edge of the sheet substrate such that the curved leading edge of the sheet substrate is flattened at said point of contact with said elastomeric cleaning roller.

[0013] In this way, the guide is arranged to abut a curved leading edge of a sheet substrate as it is carried towards an elastomeric cleaning roller. That is, the guide is able to flatten the curved leading edge by deflecting or deforming it prior to being received in a contact zone of the elastomeric cleaning roller. The outlet region of the guide is preferably provided in close proximity to the elastomeric cleaning roller so that it operably precedes the contact zone by only a short distance. However, the outlet region of the guide may be positioned at any suitable point along the first conveyor.

[0014] Advantageously, the contact cleaning apparatus is able flatten a wide range of sheet substrates. In particular, the apparatus has been found by the inventors to be effective to flatten curved leading edges for sheet substrates which are stiff or which otherwise resist deformation. That is, the apparatus is able to flatten a curved leading edge of sheet substrates with a thickness of up to 6 millimetres or more.

[0015] In certain embodiments, said guide is provided at an angle relative to said first conveyor, wherein said guide and said first conveyor are configured so as to provide a channelling of the curved leading edge as the curved leading edge approaches said contact zone. In certain embodiments, said guide includes a second conveyor, wherein said second conveyor is arranged at an angle relative to said first conveyor so as to provide said channelling of the curved leading edge.

[0016] In these ways, the guide abuts the curved leading edge so that the leading edge is directed or channelled towards the first conveyor. The second conveyor is arranged at any suitable angle to the first conveyor so as to provide an appropriate channelling. In this way, an angle may be chosen based upon a sheet substrate and the contact cleaning operating conditions. For example, an angle may be chosen based on one or more of the material properties of the sheet substrate, the operating speed of the contact cleaning apparatus, or the space within the apparatus in which to position the second conveyor.

[0017] In certain embodiments, the guide or the second conveyor may be angled relative to the first conveyor at any suitable angle, from substantially perpendicular to

substantially parallel. That is, said angle relative to said first conveyor of said guide or said second conveyor is selectably adjustable between perpendicular and parallel. In this way, the orientation of the guide, for example the second conveyor, can be adjusted to optimise processing of sheet substrates having curved leading edges with a range of deformation.

[0018] In certain embodiments, said second conveyor contactingly engages said first conveyor. In this way, the second conveyor channels the curved leading edge onto the first conveyor. In certain embodiments, the second conveyor may apply pressure to the curved leading edge. That is, the second conveyor may provide a nip effect with the first conveyor.

[0019] In certain embodiments, said second conveyor is driven. In this way, the second conveyor may actively engage the curved leading edge so as to direct it towards the elastomeric cleaning roller as well as providing a channelling effect. In certain embodiments, the second conveyor is driven due to contacting engagement with the first conveyor. In certain embodiments, the second conveyor is provided with an independent drive.

[0020] In certain embodiments, said flattening means includes an air supply manifold, wherein said air supply manifold is operable to direct a stream of air onto the curved leading edge of the sheet substrate and/or onto said contact zone such that the curved leading edge of the sheet substrate is flattened at said point of contact with said elastomeric cleaning roller. According to a further aspect of the present invention, there is provided a contact cleaning apparatus for a sheet substrate having a curved leading edge. The contact cleaning apparatus comprises an elastomeric cleaning roller and an air supply manifold configured and arranged to direct air onto a contact zone on the elastomeric cleaning roller. The contact cleaning apparatus also comprises a conveyor for carrying the sheet substrate to be cleaned towards the elastomeric cleaning roller. The air supply manifold is operable to direct a stream of air onto the curved leading edge of the sheet substrate and/or onto the contact zone such that the curved leading edge of the sheet substrate is flattened at the point of contact with the elastomeric cleaning roller.

[0021] In certain embodiments, the contact zone comprises a boundary layer of air around the surface of the elastomeric cleaning roller. In certain embodiments, the contact zone extends at least partly around the elastomeric cleaning roller. Thus, when

the stream of air from the air supply manifold is directed to the contact zone, it forms an augmented boundary layer.

[0022] When referred to herein the "contact zone" is the portion of the contact cleaning apparatus at which the leading edge of the sheet substrate engages with the elastomeric cleaning roller. More specifically, it is the region including the position at which the leading edge of the sheet substrate contacts the elastomeric cleaning roller or the boundary layer of air around it. As will be understood, this position may refer to one or more points or regions along the surface of the elastomeric cleaning roller or its boundary layer of air depending on the cross-machine shape of the leading edge.

[0023] When referred to herein, "boundary layer" is a layer of air formed on the surface of the elastomeric cleaning roller.

[0024] As referred to herein, "flattened" means that the sheet substrate leading edge is oriented to be suitably received by the elastomeric cleaning roller for cleaning. That is, approaching the contact zone the sheet substrate leading edge is flat or substantially flat so that it is received by the elastomeric cleaning roller in a manner which provides effective cleaning.

[0025] When referred to herein, "augmented boundary layer" is one having a temporary increase in thickness when measured on a radius from the centre of the elastomeric cleaning roller.

[0026] Thus, in use of the apparatus, the leading edge of the sheet substrate is deflected by the airflow into the contact zone. In this way, the sheet substrate leading edge is oriented to be received by the elastomeric cleaning roller for cleaning. The sheet substrate is flattened into the plane of the trailing sheet substrate portion allowing the airflow and / or the boundary layer to carry the sheet substrate round into the nip of the elastomeric roller without damage to the sheet substrate or incorrect engagement with the elastomeric cleaning roller, such as the sheet substrate sticking to the rollers.

[0027] In certain embodiments, the augmented boundary layer extends around the elastomeric cleaning roller until a nip gap. In this way, the leading edge of the sheet substrate may further be deflected by the augmented boundary layer to flatten the sheet and enter the nip gap between elastomeric cleaning rollers.

[0028] The airflow may be activated just before the leading edge reaches the elastomer roller so there is a temporary increase in the boundary layer

[0029] Thus, air is directed by the air supply manifold towards the contact zone of the elastomeric cleaning roller.

[0030] In certain embodiments the air supply manifold is operable to direct air directly onto the leading edge of the curved sheet in order to flatten the sheet as it approaches the elastomeric cleaning roller. The flattening of the sheet ensures that it enters the contact zone rather than engaging another part of the contact cleaning apparatus, such as a process roller or a further elastomeric cleaning roller. In this way, the flattening of the leading edge avoids crumpling of the sheet substrate because it does not engage correctly with the elastomeric cleaning roller. The contact cleaning apparatus therefore need not be stopped during the cleaning process. Furthermore, the apparatus does not require additional set up time to ensure that the leading edge is correctly engaged with or received by the elastomeric cleaning roller.

[0031] Alternatively, or in addition, the air supply manifold is operable to direct air onto the elastomeric cleaning roller. More specifically, the air supply manifold is operable to direct air onto the contact zone of the elastomeric cleaning roller. In these embodiments, an augmented boundary layer is formed at the surface of the elastomeric cleaning roller. As the leading edge of the sheet substrate contacts the augmented boundary layer, the curvature at the leading edge is removed, or significantly reduced thereby flattening the sheet substrate in the contact zone.

[0032] In certain embodiments, the airflow from the air supply manifold is selectively activated. In this way, the airflow is provided only as the leading edge of the sheet substrate reaches the elastomeric cleaning roller. In this way, the airflow provides a temporary increase in the boundary layer thickness forming the augmented boundary layer, thereby improving efficiency of the apparatus.

[0033] In certain embodiments, the air supply manifold is operable to direct air towards the contact zone at an adjustable angle relative to a reference plane extending vertically through the rotational axis of the elastomeric cleaning roller. More specifically, the adjustable angle is selectable between parallel and perpendicular to the reference plane.

[0034] In certain embodiments, the adjustable angle is selected and fixed relative to a reference plane extending vertically from the rotational axis of the elastomeric cleaning roller prior to operation of the apparatus. Any angle is selectable within the range of from parallel to the plane extending vertically from the rotational axis of the elastomeric cleaning roller and perpendicular to the same plane. The angle is selected based on

any one or more of: the velocity of the conveyor; the material of the sheet substrate or the like.

[0035] In certain embodiments, the air supply is directed tangentially onto the elastomeric cleaning roller in the contact zone.

[0036] In certain embodiments, the air supply manifold is operable to direct air towards the contact zone at an adjustable angle relative to the conveyor surface. More specifically, the adjustable angle is selectable between perpendicular to the conveyor surface and parallel to the conveyor surface.

[0037] In certain embodiments, the elastomeric cleaning roller comprises a pair of elastomeric cleaning rollers. The pair of elastomeric cleaning rollers may be opposingly arranged to form a nip gap through which a sheet substrate is conveyed.

[0038] In certain embodiments, the contact cleaning apparatus comprises multiple pairs of elastomeric cleaning rollers configured and arranged to provide one or more cleaning surfaces for the sheet substrate between each pair of rollers.

[0039] In certain embodiments, each elastomeric cleaning roller is cleaned by an adjacent adhesive roll.

[0040] In certain embodiments, the air supply manifold comprises a manifold comprising spaced apart apertures. More specifically, the manifold comprises spaced apart air delivery apertures for the output of air from the manifold.

[0041] In certain embodiments, the manifold is tubular.

[0042] In certain embodiments, the manifold comprises a plurality of spaced apart pin holes.

[0043] In certain embodiments, the manifold is formed of a metal or plastic material. Other suitable materials will be known to the skilled person.

[0044] In certain embodiments, the air supply manifold is operably coupled to an air supply. The air supply is operable to deliver air to the air supply manifold.

[0045] In certain embodiments, the contact cleaning apparatus comprises a sensor configured and arranged to detect the leading edge of the sheet substrate.

[0046] In certain embodiments, the sensor is operably coupled to the air supply. In use of the apparatus, the sensor detects the leading edge of the sheet substrate and causes the air supply to deliver air to the air supply manifold. The air supply manifold in turn

directs air onto the leading edge of the sheet substrate and/or onto the contact zone of the elastomeric cleaning roller.

[0047] In certain embodiments, the air supply directed at the curved leading edge of the sheet substrate unbends the sheet before the contact zone of the elastomeric cleaning roller. Thus, incorrect engagement of the sheet substrate with the elastomeric cleaning roller is prevented. Creasing of the sheet or wrapping of the sheet substrate around the elastomeric cleaning roller is also prevented. Furthermore, the air serves to facilitate transfer of the sheet substrate through the cleaning apparatus.

[0048] In certain embodiments, the air directed onto the elastomeric cleaning roller contact zone creates an augmented boundary layer over the surface of the elastomeric cleaning roller. In this way, the air ensures that the sheet substrate is cleaned by the elastomeric cleaning roller surface without making contact.

[0049] In certain embodiments, air is supplied from the air supply manifold in pulses. More specifically, the pulses are generated when the sensor detects the leading edge of the sheet substrate adjacent to the elastomeric cleaning roller. Each pulse of air flattens the leading surface as it approaches the contact zone.

[0050] In certain embodiments, air flow through the air flow manifold is activated by a sensor detecting the curved leading edge of a sheet substrate a predetermined distance from the contact zone. Additionally, or alternatively, air flow through the air flow manifold is deactivated as the leading edge engages the contact zone. In these ways, the air flow is used to flatten the curved leading edge only when it approaches the contact zone. Air flow only provided when the curved leading edge is within the operable range of the air flow manifold. The air flow provided by the air supply is thereby utilised efficiently.

[0051] In certain embodiments, the conveyor is configured and arranged to deliver the sheet substrate to the contact zone.

[0052] In certain embodiments, the sheet substrate is a film. More specifically, the film is a thin film. Yet more specifically, the film is a copper foil or a thin film polymer.

Brief Description of the Drawings

[0053] Embodiments of the invention are now described, by way of example only, hereinafter with reference to the accompanying drawings, in which:

Figure 1 illustrates a schematic representation of a contact cleaning apparatus with the air supply to the air flow manifold turned off, in a first configuration;

Figure 2 illustrates a schematic representation of the contact cleaning apparatus of Figure 1, in a second configuration;

Figure 3 illustrates a schematic representation of the contact cleaning apparatus of Figure 1, in a third configuration;

Figure 4 illustrates a schematic representation the contact cleaning apparatus of Figure 1, in a fourth configuration;

Figure 5 illustrates a schematic representation of a contact cleaning apparatus with the air supply to the air flow manifold turned on according to an embodiment, in a first configuration;

Figure 6 illustrates a schematic representation of the contact cleaning apparatus of Figure 5, in a second configuration;

Figure 7 illustrates a schematic representation of the contact cleaning apparatus of Figure 5, in a third configuration; and

Figure 8 illustrates a schematic representation of a further example contact cleaning apparatus according an aspect of the invention.

Detailed Description

[0054] Certain terminology is used in the following description for convenience only and is not limiting. The words 'right', 'left', 'lower', 'upper', 'front', 'rear', 'upward', 'down' and 'downward' designate directions in the drawings to which reference is made and are with respect to the described component when assembled and mounted. The words 'inner', 'inwardly' and 'outer', 'outwardly' refer to directions toward and away from, respectively, a designated centreline or a geometric centre of an element being described (e.g. central axis), the particular meaning being readily apparent from the context of the description.

[0055] Further, as used herein, the terms 'connected', 'attached', 'coupled', 'mounted' are intended to include direct connections between two members without any other members interposed therebetween, as well as, indirect connections between members in which one or more other members are interposed therebetween. The terminology includes the words specifically mentioned above, derivatives thereof, and words of similar import.

[0056] Further, unless otherwise specified, the use of ordinal adjectives, such as, "first", "second", "third" etc. merely indicate that different instances of like objects are being

referred to and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking or in any other manner.

[0057] Like reference numerals are used to depict like features throughout.

[0058] Referring firstly to Figure 1, there is shown a contact cleaning apparatus 1. The contact cleaning apparatus comprises a first pair of elastomeric cleaning rollers and a second pair of elastomeric cleaning rollers. The first pair of elastomeric cleaning rollers comprises a first elastomeric cleaning roller 24 and a second elastomeric cleaning roller 26 mounted in the path of a conveyor 16. The conveyor 16 is driven by two transport rollers 12,14 in order to transport a substrate 80 (i.e. a sheet 80) along the conveyor 16. The first elastomeric cleaning roller 24 is elongate and generally cylindrical in shape, and is mounted on a holder (not shown) having a rotational axis perpendicular to the plane of view about which the first elastomeric cleaning roller 24 is free to rotate. The first elastomeric cleaning roller 24 comprises a silicone elastomer layer in this particular example, but other material are also envisaged. The second elastomeric cleaning roller 26 is generally cylindrical in shape, and comprises a silicone elastomer layer. The second elastomeric cleaning roller 26 is mounted on a holder (not shown) having a rotational axis perpendicular to the plane of view and parallel to that of the first elastomeric cleaning roller 24 about which the second elastomeric cleaning roller 26 is free to rotate. The first elastomeric cleaning roller 24 and the second elastomeric cleaning roller 26 are mounted so as to be in contact with one another such that the first elastomeric cleaning roller 24 and the second elastomeric cleaning roller 26 rotate in opposite directions about their respective rotational axes. The first elastomeric cleaning roller 24 rotates anticlockwise while the second elastomeric cleaning roller 26 rotates clockwise.

[0059] The first elastomeric cleaning roller 24 and the second elastomeric cleaning roller 26 are mounted so as to receive the substrate from the conveyor. Once the substrate has been received, both the first elastomeric cleaning roller 24 and the second elastomeric cleaning roller 26 are arranged to be in contact with the surface of the substrate 80. The first elastomeric cleaning roller 24 is arranged to contact the upper surface of the substrate 80. The second elastomeric cleaning roller 26 is arranged to contact the lower surface of the substrate 80. The substrate 80 has a curved end 82 closest to the rollers.

[0060] The second pair of rollers comprises a third elastomeric cleaning roller 34 and a fourth elastomeric cleaning roller 36 mounted in the path of a conveyor 16 downstream

from the first pair of rollers. The third elastomeric cleaning roller 34 is elongate and generally cylindrical in shape, and is mounted on a holder (not shown) having a rotational axis perpendicular to the plane of view about which the third elastomeric cleaning roller 34 is free to rotate. The fourth elastomeric cleaning roller 36 is mounted on a holder (not shown) having a rotational axis perpendicular to the plane of view and parallel to that of the third elastomeric cleaning roller 34 about which the fourth elastomeric cleaning roller 36 is free to rotate. The third elastomeric cleaning roller 34 and the fourth elastomeric cleaning roller 36 are mounted so as to be in contact with one another such that the third elastomeric cleaning roller 34 and the fourth elastomeric cleaning roller 36 rotate in opposite directions about their respective axes. The third elastomeric cleaning roller 34 rotates clockwise while the fourth elastomeric cleaning roller 36 rotates anticlockwise.

[0061] The third elastomeric cleaning roller 34 and the fourth elastomeric cleaning roller 36 are mounted so as to receive the substrate from the first and second elastomeric cleaning rollers 24, 26. Once the substrate has been received, both the third elastomeric cleaning roller 34 and the fourth elastomeric cleaning roller are arranged to be in contact with the surface of the substrate 80. The third elastomeric cleaning roller 34 is arranged to contact the upper surface of the substrate 80. The fourth elastomeric cleaning roller 36 is arranged to contact the lower surface of the substrate 80. The first pair of rollers 24,36 and the second pair of rollers 34,36 may each be provided with a nip gap through which the substrate 80 is to be conveyed.

[0062] The sheet substrate 80 to be cleaned is positioned on the surface of the conveyor 16 which, in Figure 1, conveys the sheet substrate 80 from left to right. The substrate 80 passes between the first pair of elastomeric cleaning rollers and second pair of elastomeric cleaning rollers consecutively. That is, the substrate 80 firstly passes between the first elastomeric cleaning roller 24 and the second elastomeric cleaning roller 26. The first elastomeric cleaning roller 24 rotates anticlockwise while the second elastomeric cleaning roller 26 rotates clockwise, moving the substrate 80 to the right.

[0063] The first elastomeric cleaning roller 24 contacts the upper surface of the substrate 80, removing debris therefrom. The inherent polarity of the material used to form the first elastomeric cleaning roller 24 attracts the debris from the upper surface of the substrate 80 and causes the debris to stick to the surface of the first elastomeric cleaning roller 24. The relative attractive force between the surface of the first elastomeric cleaning roller 24 and the debris is greater than that between the debris and the surface of the substrate 80, allowing the debris to be removed.

[0064] The second elastomeric cleaning roller 26 rotates clockwise. The second elastomeric cleaning roller 26 contacts the lower surface of the substrate 80, removing debris therefrom. The inherent polarity of the material used to form the second elastomeric cleaning roller 26 attracts the debris from the bottom surface of the substrate 80 and causes the debris to stick to the surface of the second elastomeric cleaning roller 26. The relative attractive force between the surface of the second elastomeric cleaning roller 26 and the debris is greater than that between the debris and the surface of the substrate 80, allowing the debris to be removed.

[0065] The substrate 80 is then received by the second pair of elastomeric cleaning rollers. The substrate 80 passes between the third elastomeric cleaning roller 34 and the fourth elastomeric cleaning roller 36. The third elastomeric cleaning roller 34 rotates clockwise while the fourth elastomeric cleaning roller 36 rotates anticlockwise, moving the substrate 80 to the right.

[0066] The third elastomeric cleaning roller 34 contacts the lower surface of the substrate 80, removing debris therefrom. The inherent polarity of the material used to form the third elastomeric cleaning roller 34 attracts the debris from the lower surface of the substrate 80 and causes the debris to stick to the surface of the third elastomeric cleaning roller 34. The relative attractive force between the surface of the third elastomeric cleaning roller 34 and the debris is greater than that between the debris and the surface of the substrate 80, allowing the debris to be removed.

[0067] The fourth elastomeric cleaning roller 36 rotates anticlockwise. The fourth elastomeric cleaning roller 36 contacts the upper surface of the substrate 80, removing debris therefrom. The inherent polarity of the material used to form the fourth elastomeric cleaning roller 36 attracts the debris from the upper surface of the substrate 80 and causes the debris to stick to the surface of the fourth elastomeric cleaning roller 36. The relative attractive force between the surface of the fourth contact cleaning roller 36 and the debris is greater than that between the debris and the surface of the substrate 80, allowing the debris to be removed. The second pair of contact cleaning rollers are implemented to remove any further debris that is not removed by the first pair of contact cleaning rollers.

[0068] A first adhesive roll 20 and a second adhesive roll 22 are also provided. The adhesive rolls 20,22 are generally cylindrical in shape comprising a body having a surface on which adhesive having a rotational axis perpendicular to the plane of view and parallel to the axes of the elastomeric cleaning rollers 24,26,34,36, about which the

adhesive rolls 20,22 are free to rotate. The first adhesive roll 20 comprises a paper base and an adhesive on the base layer. The second adhesive roll 22 comprises a paper base and an adhesive on the base layer.

[0069] The first adhesive roll 20 rotates against the first elastomeric cleaning roller 24 and the fourth elastomeric cleaning roller 36. In this way the respective surfaces of the first and the fourth cleaning rollers 24,36 and the first adhesive roll 20 are close enough such that debris removed from the upper surface of the substrate 80 are transferred to the first adhesive roll 20. The adhesive force between the debris on the first and on the fourth elastomeric cleaning rollers 24,36 and the first adhesive roll 20 is greater than the adhesion force holding the debris onto the surface of either the first or fourth elastomeric cleaning rollers 24,36, allowing the debris to be transferred.

[0070] The second adhesive roll 22 rotates against the second elastomeric cleaning roller 26 and the third elastomeric cleaning roller 34. In this way, the respective surfaces of the second and third elastomeric cleaning rollers 26,34 and the second adhesive roll 22 are close enough such that debris removed from the lower surface of the substrate 80 are transferred to the second adhesive roll 22. The adhesive force between the debris on the second and on the third elastomeric cleaning rollers 26, 34, and the second adhesive roll 22 is greater than the adhesion force holding the debris onto the surface of either the second and third elastomeric cleaning rollers 26,34, allowing the debris to be transferred.

[0071] The contact cleaning apparatus 1 is further provided with an air supply manifold 40 fluidly coupled to an air supply (not shown). The air supply manifold 40, shown in schematic cross section, is provided in the form of a cylinder having holes therein. One of the holes 42 is shown in the depicted embodiment. There may be provided a plurality of holes 42 in the form of pin holes spaced apart along the longitudinal axis of the manifold 40.

[0072] An air supply (not shown) is configured to supply air into the air manifold, such that air can be expelled through the hole 42. The air manifold 40 is mounted at a position located upstream of the first pair of contact cleaning rollers 24,26 so as to direct a stream of air onto the sheet substrate 80. More specifically, the air manifold 40 is designed to eject a stream of air onto the sheet substrate 80 before the sheet substrate 80 engages a contact zone at the surface of the first and second elastomeric cleaning rollers 24, 26.. This operation will be described in more detail with reference to Figures 5 to 7. Alternatively, or in addition, the air supply manifold 40 is configured and arranged to

eject a stream of air onto the contact zone at the surface of the elastomeric rollers 24, 26.

[0073] Referring now to Figures 2 and 3, the substrate 80 is transported along the conveyor 16 towards the first pair of elastomeric cleaning rollers 24,26. The curved leading edge 82 of the substrate 80 tends upwards away from the conveyor 16 such that the substrate 80 is not planar.

[0074] In the example shown in Figures 2 and 3, the air supply manifold is deactivated and so does not provide any air. Elastomeric cleaning rollers are typically driven to very high speeds in order to facilitate cleaning. Consequently, and as shown in Figure 3, as the curved leading edge 82 of the substrate 80 collides with the first elastomeric cleaning roller 24.

[0075] As shown in Figure 4, due to the high impact speed, the substrate 80 crumples against the first elastomeric cleaning roller 24. In the absence of an air supply, the the curved edge of substrate 80 wraps around the first elastomeric cleaning roller 24. Thus, instead of passing between the first and second elastomeric cleaning rollers 24, 26, for cleaning, the substrate 80 causes the apparatus to be jammed or fail. The apparatus 1 must then be repaired and undergo maintenance.

[0076] With reference now to Figures 5 to 7, the operation of a contact cleaning apparatus 101 utilising the aforementioned air manifold 140 will now be described. The contact cleaning apparatus 101 is substantially the same as contact cleaning apparatus 1 in Figures 1 to 4. With reference firstly to Figure 5, the sheet substrate 180 is transported along the conveyor 116 driven by the transport rollers 112,114. The free leading edge 182 of the substrate 180 is approaches the first pair of contact cleaning rollers 124,126.

[0077] Referring now to Figures 6 and 7, air is expelled from the air outlet 142 of the air supply manifold 140 along a direction generally denoted by arrow 144. Thus, a stream of air is directed towards a contact zone of the first elastomeric cleaning roller 126. The stream of air is directed onto a curved leading edge 182 of the substrate sheet 180 as it approaches the contact zone. In this example, the air is directed onto the curved leading edge 182 of the substrate 180 to flatten the substrate 180.

[0078] Air may, in addition or alternatively be expelled from the air outlet 142 onto a contact zone between the first pair of elastomeric cleaning rollers 124,126 and the curved leading edge 182 of the substrate 180. It is also envisaged that the stream of air may be directed towards a location upstream of the contact zone. In this way, when the

curved leading edge 182 of the sheet substrate 180 is conveyed towards the contact zone, the substrate 180 may be flattened before the sheet substrate 180 is cleaned by the first and second pair of elastomeric cleaning rollers 124,126,134,136.

[0079] By directing air at the contact zone of the first pair of elastomeric rollers 124, 126, the boundary layer of air around the second elastomeric roller 126 is temporarily augmented. In these examples, the augmented boundary layer flattens the leading edge 182 of the sheet substrate 180 in the contact zone. Consequently, as the sheet substrate 180 is correctly oriented to be received and cleaned by the first pair of elastomeric cleaning rollers.

[0080] The substrate 180 may be flattened at any point upstream from the elastomeric cleaning rollers 124,126,134,136.

[0081] In this particular embodiment, air is supplied at an angle of 20 degrees relative to a reference plane extending vertically from the rotational axis of the second elastomeric cleaning roller 126. The angle may be a fixed angle.

[0082] The angle of the air supply directed from the air outlet 142 of the air manifold 140 will depend on the speed of transfer of substrate 180 into the cleaning zone. The angle may be changed to any number of fixed angles between perpendicular and parallel to the reference plane. It is envisaged that air may be supplied at a different angle, such as an angle between parallel to and perpendicular to the reference plane.

[0083] In some examples, the angle of the air manifold outlet may be varied relative to a surface of the reference plane.

[0084] In some examples, the stream of air of the cleaning contact apparatus may be selectively activated. In this way, the stream of air may be operable only when a leading edge is approaching the contact zone. Once the leading edge has engaged with the contact zone, then the air supply is no longer required in order to ensure correct operation of the apparatus. The stream of air is thus deactivate as the remainder of the sheet substrate is conveyed through contact zone.

[0085] In some examples, the cleaning contact apparatus is provided with a detection sensor (not shown). The detection sensor detects the leading edge of the substrate on the conveyor as it approaches the contact zone to activate the stream of air. For example, when the leading edge of the substrate is detected by the sensor, a controller communicates with the air supply to deliver air to the air supply manifold which in turn delivers the air through the outlet.

[0086] In some examples, the stream of air may be expelled through the outlet of the manifold in pulses. Optionally, the pulsed stream of air may be selectively activated, for example employing a detection sensor to detects the leading edge of the substrate on the conveyor.

[0087] Referring now to Figure 8, there is shown a further example contact cleaning apparatus 201 for a sheet substrate with a curved leading edge according to an aspect of the invention. Where the features are the same as the previous examples, the reference numbers are the same, other than the initial digit is a "2".

[0088] Thus, the example of Fig. 8 shows a first pair of elastomeric cleaning rollers provided, including first and second elastomeric cleaning rollers 224, 226 mounted to receive a sheet substrate 280 from a first conveyor 216. A flattening means is disposed proximate the first conveyor 216, the flattening means configured to operably engage the curved leading edge 282 of the sheet substrate 280 such that the curved leading edge 282 is flattened at a point of contact with the first pair of elastomeric cleaning rollers 224, 226.

[0089] In the example shown in Figure 8 the flattening means is a second conveyor 296. The second conveyor 296 is provided proximate said first conveyor 216. The second conveyor 296 is configured to operably engage the curved leading edge 282 of the sheet substrate 280 such that the curved leading edge 282 is flattened at a point of contact with the second elastomeric cleaning roller 226.

[0090] The first pair of elastomeric cleaning rollers 224, 226 are substantially the same as the first pair of elastomeric cleaning rollers 24, 26 of the other examples described herein. Each of the first pair of elastomeric cleaning rollers 224,226 is rotatably mounted on a holder (not shown) so as to receive the substrate from the conveyor.

[0091] A second pair of elastomeric cleaning rollers 234, 236 is provided downstream from the first pair of rollers. The second pair of rollers 234, 236 of the example shown in Fig. 8 are substantially the same as the first pair of elastomeric cleaning rollers 34, 36 of the other examples described herein. Each roller of the second pair is rotationally mounted on a holder (not shown). The second pair of elastomeric cleaning rollers, 234, 236 are arranged to receive the sheet substrate 280 from the first pair of elastomeric cleaning rollers 224, 226.

[0092] The first conveyor 216 is driven by first and second transport rollers 212, 214. In this way, the first conveyor 216 is adapted to transport a sheet substrate 280 thereon.

The first and second transport rollers 212, 214 of the first conveyor 216 are arranged within opposing end regions of the first conveyor 216.

[0093] The second conveyor 296 is driven by first and second transport rollers 292, 294 arranged within opposing end regions of the second conveyor 296. The first transport roller 294 is position proximate both the first conveyor 216 and the first pair of elastomeric cleaning rollers 224, 226. The second transport roller 292 is positioned distal to the first pair of elastomeric cleaning rollers 224, 226.

[0094] The first pair of elastomeric cleaning rollers 224, 226 and the second pair of rollers 234, 236 are each be provided with a nip gap through which the substrate 280 is to be conveyed.

[0095] The contact cleaning apparatus 201 includes a first adhesive roll 220 and a second adhesive roll 222. The first and second adhesive rolls 220, 222 are mounted and arranged to transfer debris from the first and second pairs of elastomeric cleaning rollers 224, 226, 234, 236 in a similar manner to those other examples described herein.

[0096] In use, the first conveyor 216 is driven by its first and second transport rollers 212, 214. The first conveyor 216 is driven in a direction, D2, so the surface region supporting the sheet substrate 280 is moved towards the first pair of elastomeric cleaning rollers 224, 226. In this way, when a sheet substrate 280 is carried on the first conveyor 216, it moves in a direction, D1, towards the first pair of elastomeric cleaning rollers 224, 226.

[0097] In use, the second conveyor 296 is driven by its first and second transport rollers 292, 294. The second conveyor 296 is driven in a direction, D3, such that the surface of the second conveyor 296 which engages the curved leading edge 282 moves towards the first transport roller. In this way, surface engaging the curved leading edge 282 moves towards the first pair of elastomeric cleaning rollers.

[0098] The second conveyor 296 is arranged at an angle relative to the first conveyor 216. Due to their relative positioning, the second conveyor 296 is provided in contacting engagement with the first conveyor 216 proximate the first pair of elastomeric cleaning rollers 224, 226. That is, the first and second conveyors 216, 296 provide a nip gap through which the substrate 280 is to be conveyed.

[0099] The relative angular orientation of the first and second conveyors, 216, 296 enables the first and second conveyors 216, 296 to channel the curved leading edge 282 as the curved leading edge 282 moves towards the first pair of cleaning rollers 224,

226. That is, due to the decreasing gap between the first and second conveyors, 216, 296, the curved leading edge is made flat as it approaches the nip gap of the first and second conveyors 216, 296. Consequently, the curved leading edge may be conveniently and easily flattened prior to being received by the elastomeric cleaning rollers.

[00100] In certain examples, the flattening means is any guide operable to engage and flatten a curved leading edge as it moves on a first conveyor. Suitable guides may include a surface which is suitably angled, curved or profiled so that it provides a flattening of the curved leading edge as it moves on the first conveyor. Additionally, or alternatively, a guide may include ridges, projections or ribs, optionally oriented in the direction of movement of the curved leading edge.

[00101] In certain examples, a guide may be provided with a surface treatment or coating. In this way, the guide may provide a channelling effect with low friction between the guide and the curved leading edge.

[00102] In certain examples, the flattening means, such as a guide or second conveyor may be selectively adjustable. In this way, the flattening means may positioned at varying positions and angles relative to the first conveyor.

[00103] Through the description and claims of this specification, the words “comprise” and “contain” and variations of them mean “including but not limited to”, and they are not intended to (and do not) exclude other moieties, additives, components, integers or steps. Throughout the description and claims of this specification, the singular encompasses the plural unless the context otherwise requires. In particular, where the indefinite article is used, the specification is to be understood as contemplating plurality as well as singularity, unless the context requires otherwise.

[00104] Features, integers, characteristics, compounds, chemical moieties or groups described in conjunction with a particular aspect, embodiment or example of the invention are to be understood to be applicable to any other aspect, embodiment or example described herein unless incompatible therewith. All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive. The invention is not restricted to the details of any foregoing embodiments. The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract or

drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

[00105] It will be appreciated by persons skilled in the art that the above embodiment(s) have been described by way of example only and not in any limitative sense, and that various alterations and modifications are possible without departing from the scope of the invention as defined by the appended claims. Various modifications to the detailed designs as described above are possible.

CLAIMS

1. A contact cleaning apparatus for a sheet substrate having a curved leading edge comprising:

an elastomeric cleaning roller and a first conveyor for carrying the sheet substrate to be cleaned towards said elastomeric cleaning roller, wherein said elastomeric cleaning roller comprises a contact zone arranged to receivingly engage the sheet substrate from said first conveyor, and

a flattening means disposed proximate said first conveyor, wherein said flattening means is configured to operably engage the curved leading edge of the sheet substrate such that the curved leading edge of the sheet substrate is flattened at a point of contact with the elastomeric cleaning roller.

2. A contact cleaning apparatus according to claim 1, wherein said flattening means comprises a guide, opposingly arranged with said first conveyor, and configured to contactingly engage the curved leading edge of the sheet substrate such that the curved leading edge of the sheet substrate is flattened at said point of contact with said elastomeric cleaning roller.

3. A contact cleaning apparatus according to claim 2, wherein said guide is provided at an angle relative to said first conveyor, and wherein said guide and said first conveyor are configured so as to provide a channelling of the curved leading edge as the curved leading edge approaches said contact zone.

4. A contact cleaning apparatus according to claim 3, wherein said angle of said guide relative to said first conveyor is selectably adjustable between perpendicular and parallel.

5. A contact cleaning apparatus according to claim 3 or claim 4, wherein said guide comprises a second conveyor, and wherein said second conveyor is arranged at an angle relative to said first conveyor so as to provide said channelling of the curved leading edge.

6. A contact cleaning apparatus according to claim 5, wherein said second conveyor contactingly engages said first conveyor.

7. A contact cleaning apparatus according to claim 5 or claim 6, wherein said second conveyor is driven.

8. A contact cleaning apparatus according to claim 1, wherein said flattening means comprises an air supply manifold, wherein said air supply manifold is operable to direct a stream of air onto the curved leading edge of the sheet substrate and/or onto said contact zone such that the curved leading edge of the sheet substrate is flattened at said point of contact with said elastomeric cleaning roller.

9. A contact cleaning apparatus for a sheet substrate having a curved leading edge comprising:

an elastomeric cleaning roller and an air supply manifold configured and arranged to direct air onto a contact zone on said elastomeric cleaning roller;

and a conveyor for carrying the sheet substrate to be cleaned towards said elastomeric cleaning roller, wherein said air supply manifold is operable to direct a stream of air onto the curved leading edge of the sheet substrate and/or onto said contact zone such that the curved leading edge of the sheet substrate is flattened at a point of contact with said elastomeric cleaning roller.

10. A contact cleaning apparatus according to claim 8 or claim 9 wherein said elastomeric cleaning roller comprises a rotational axis and wherein said air supply manifold is operable to direct air at the curved leading edge of the sheet substrate and/or onto said contact zone of said elastomeric cleaning roller at an adjustable angle relative to a reference plane extending vertically through said rotational axis.

11. A contact cleaning apparatus according to any one of claims 8 to 10, wherein said air supply manifold comprises a tubular manifold comprising spaced apart air delivery apertures.

12. A contact cleaning apparatus according to any one of claims 8 to 11, wherein said stream of air is selectively activated.

13. A contact cleaning apparatus according to claim 12, comprising a sensor arranged to operably detect the leading edge of the sheet substrate prior to engagement with said contact zone, and wherein, in response to detecting the leading edge, said sensor operably activates said stream of air.

14. A contact cleaning apparatus according to any one of claims 10 to 13, wherein said adjustable angle of said air supply manifold is selectable between perpendicular to said reference plane and parallel to said reference plane.

15. A contact cleaning apparatus according to claim 10 to claim 14, wherein said adjustable angle is selected and fixed relative to said reference plane prior to operation of said apparatus.

16. A contact cleaning apparatus according to any one of the preceding claims wherein said elastomeric cleaning roller comprises a pair of elastomeric cleaning rollers opposingly arranged to form a nip gap through which the sheet substrate is conveyed.

17. A contact cleaning apparatus according to any preceding claim, wherein said elastomeric cleaning roller comprises at least one pair of elastomeric cleaning rollers configured and arranged to provide a cleaning surface for the sheet substrate between each pair of rollers.

18. A contact cleaning apparatus according to any one of the preceding claims, wherein each elastomeric cleaning roller is cleaned by an adjacent adhesive roll.

19. A contact cleaning apparatus according to any preceding claim, wherein said contact zone extends at least partly around said elastomeric cleaning roller.

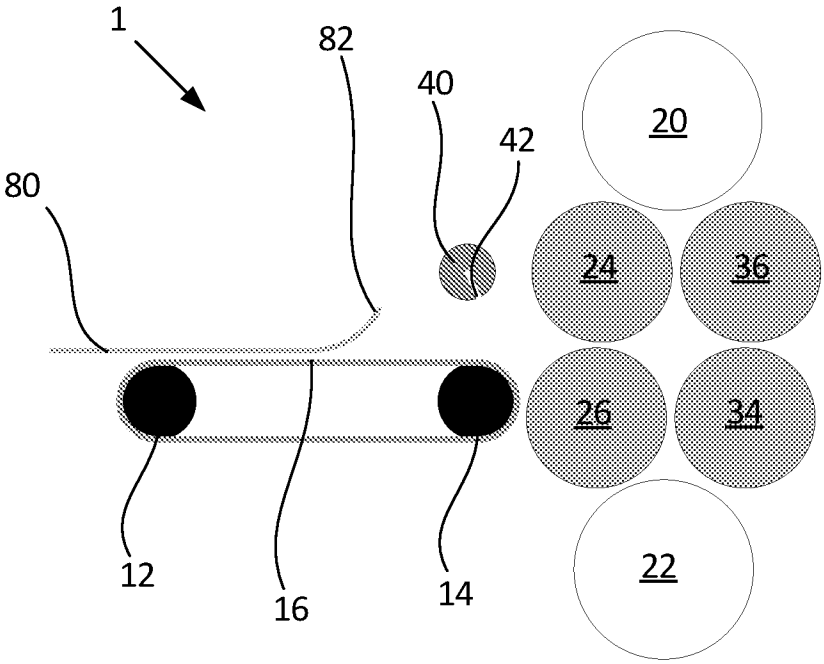
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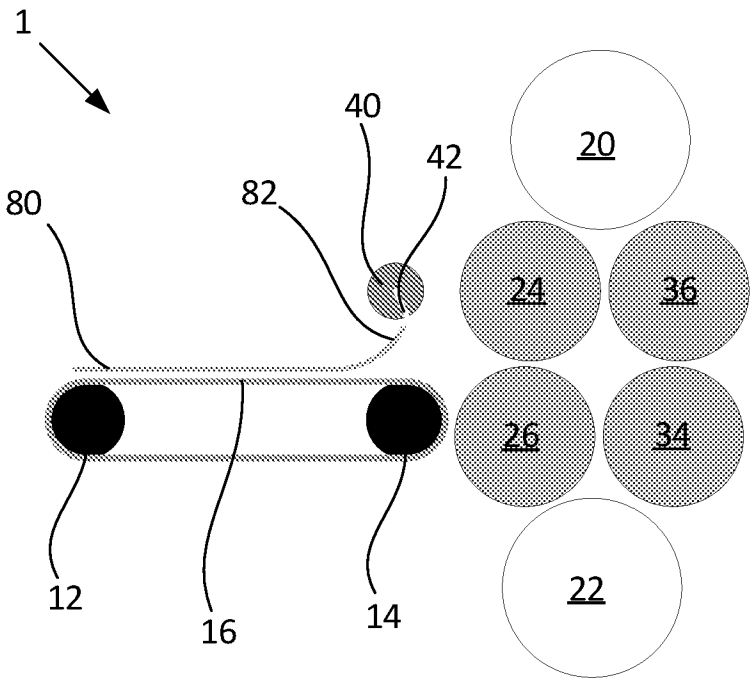
FIG. 1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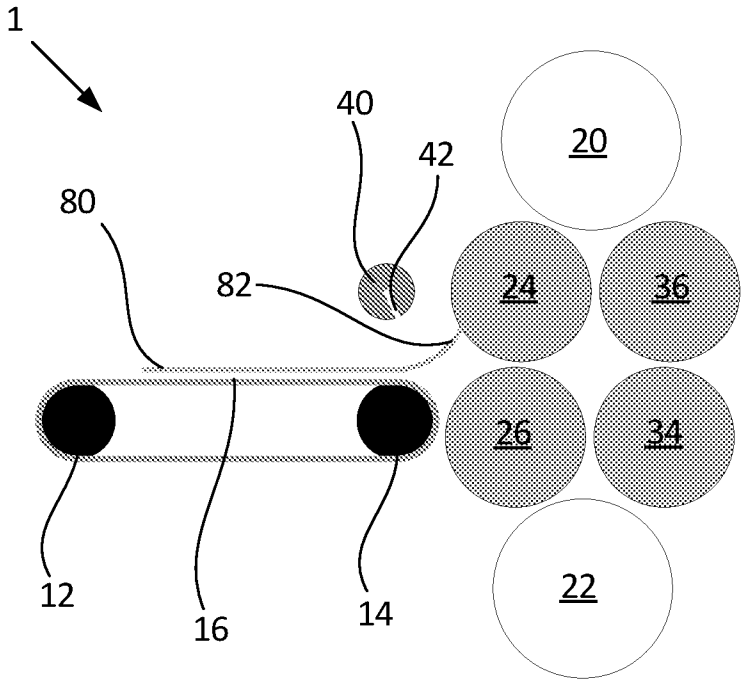
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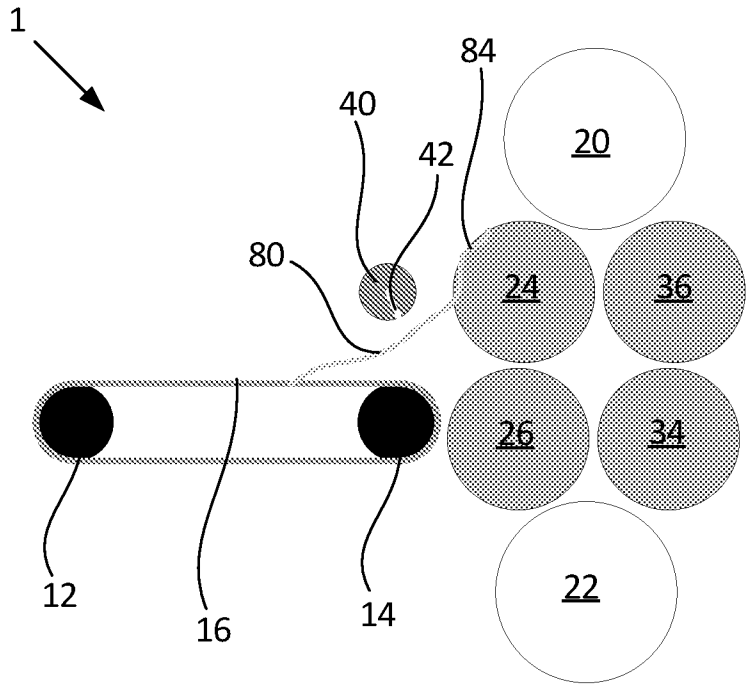
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FIG. 4

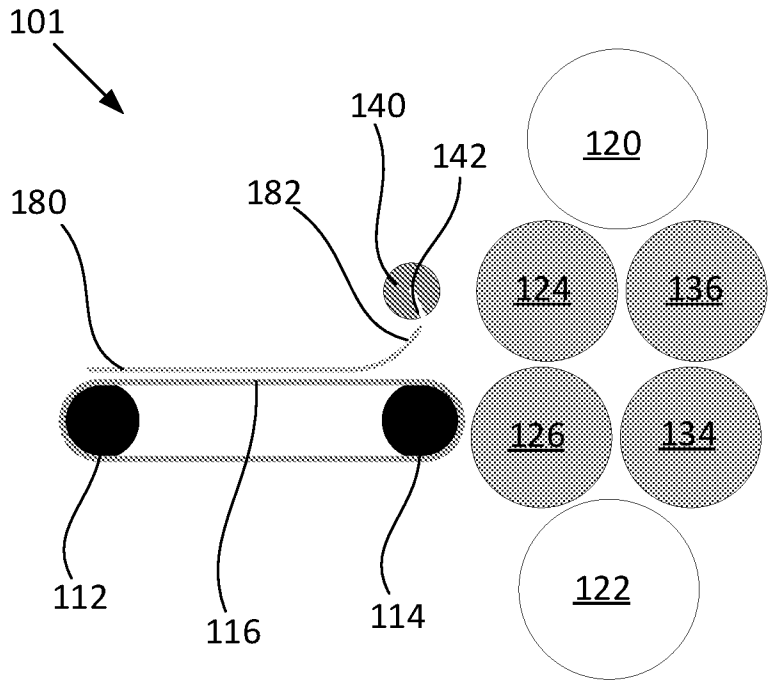
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FIG. 5

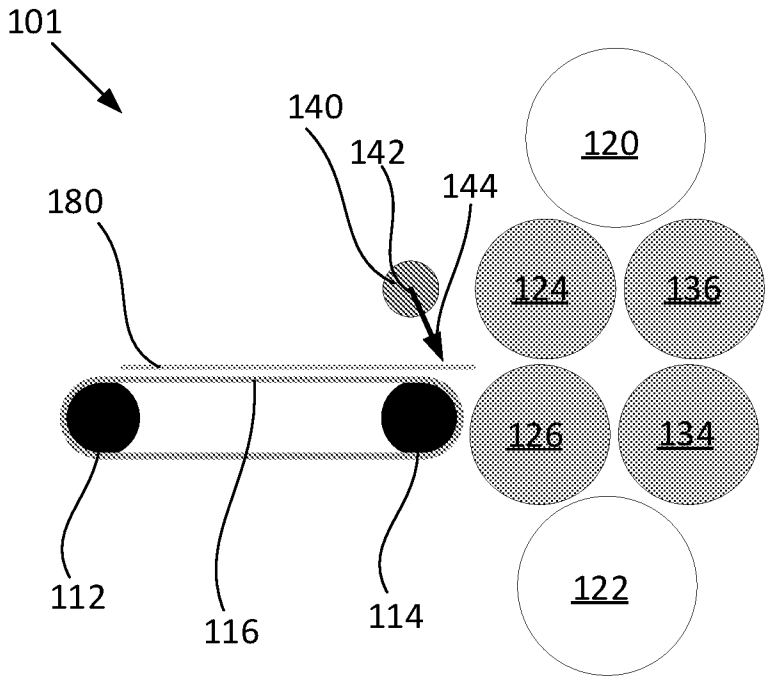
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FIG. 6

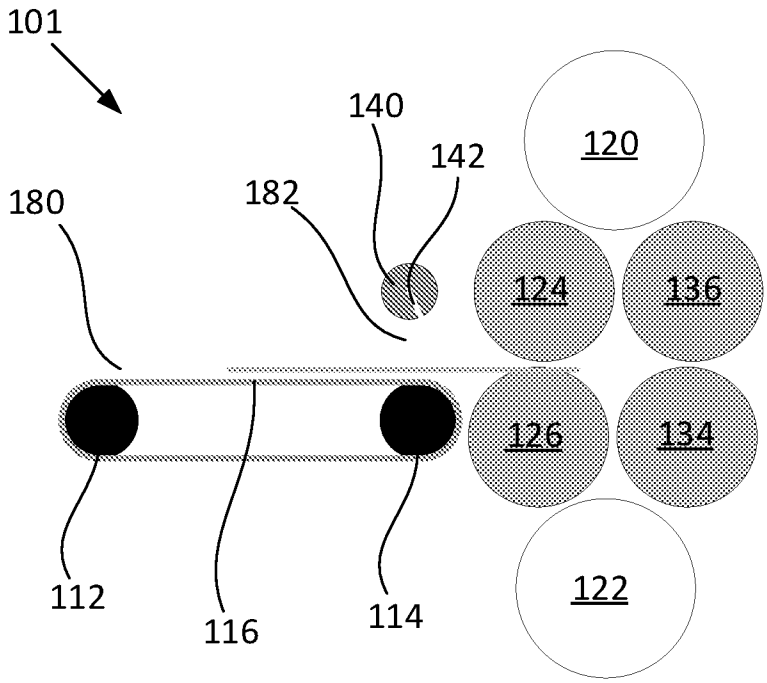
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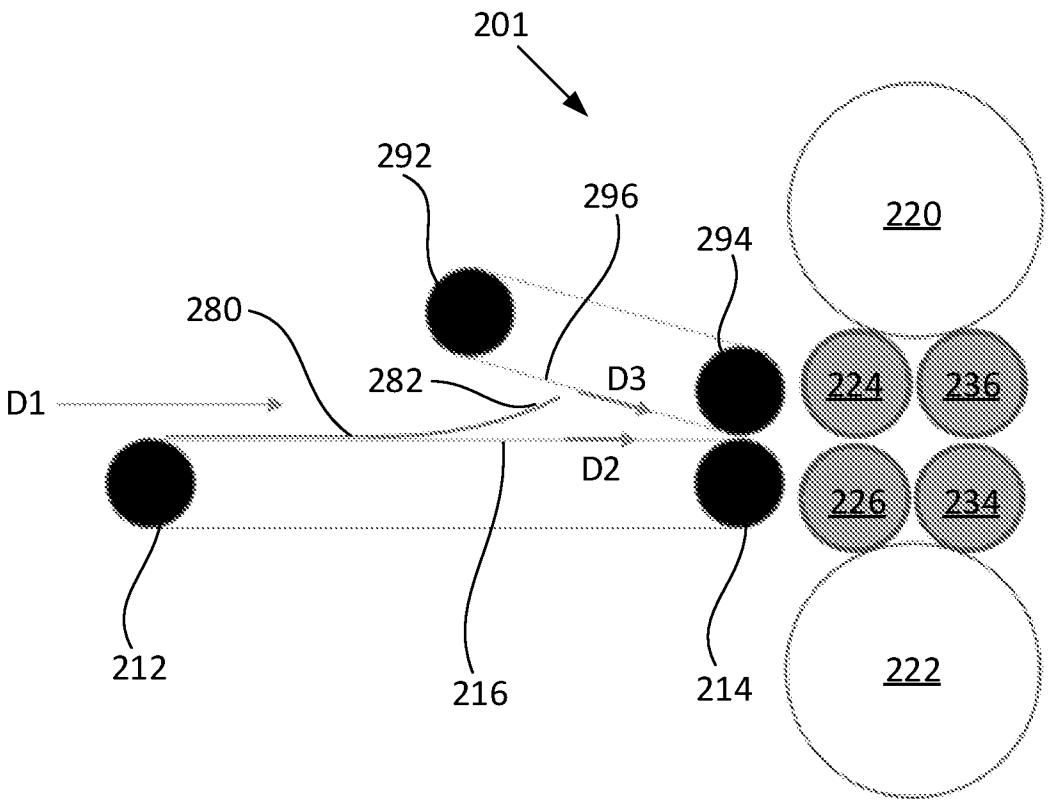
FIG. 7


201
292
296
220
294
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D1
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D3
224
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D2
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214
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FIG. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2021/019863

A. CLASSIFICATION OF SUBJECT MATTER
INV. B08B1/00 B08B1/02 B08B1/04 B08B7/00 B08B6/00
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)
B08B

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 5 913 345 A (CORRADO FRANK C [US] ET AL) 22 June 1999 (1999-06-22) column 4, line 46 - column 5, line 14 column 6, lines 13-53; figures 2,6,11 column 7, lines 10-12	1-3, 16-19 8
X A	WO 2015/147388 A1 (PARK GYEONGHWAN [KR]) 1 October 2015 (2015-10-01) the whole document	1 2-7, 16-19
A	GB 2 492 991 A (ITW CS UK LTD [GB]) 23 January 2013 (2013-01-23) page 30, paragraph 5; figure 4	1-7, 16-19

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 June 2021	25/06/2021

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Béguin-Adriaenssens

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2021/019863

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5913345 A	22-06-1999	NONE	
WO 2015147388 A1	01-10-2015	KR 20150112380 A	07-10-2015
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GB 2492991 A	23-01-2013	GB 2492991 A	23-01-2013
		WO 2013011471 A1	24-01-2013