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(71) Applicant: **Inopaq Technologies Sàrl**
1814 La Tour-de-Peliz (CH)

(72) Inventor: **Merminod, Antoine**
1188 Gimel (CH)

(74) Representative: **Ganguillet, Cyril et al**
ABREMA
Agence Brevets & Marques Ganguillet
Avenue du Théâtre 16
P.O. Box 5027
1002 Lausanne (CH)

(54) **PRINTED SHEET INSPECTION SYSTEM AND SHEET-FED PRINTING PRESS COMPRISING THE SAME**

(57) There is described a printed sheet inspection system configured to inspect printed sheets (1) being transported by a transport cylinder (6) of a sheet-fed printing press, which printed sheet inspection system comprises an imaging unit (4) located proximate to a circumferential surface of the transport cylinder (6), which imaging unit (4) is configured to acquire an image of a printed surface of the printed sheet (1) as the printed sheet (1) moves past the imaging unit (4) under the action of the transport cylinder (6). The sheet inspection system further comprises a blowing unit (5) coupled to an air diffuser (2), which air diffuser (2) is positioned proximate to the circumferential surface of the transport cylinder (6) and extends along a portion of the circumferential surface of the transport cylinder (6), the blowing unit (5) and air diffuser (2) being configured to produce an air pressure zone (Z7) and form an air cushion zone (Z6), laterally containing the air pressure zone (Z7), which press the printed sheet (1) against the circumferential surface of the transport cylinder (6).

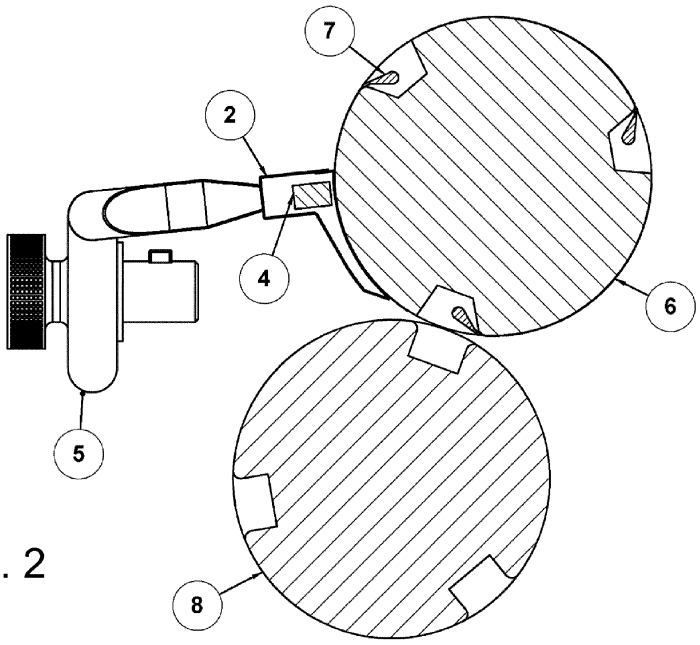

Fig. 2

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Description

TECHNICAL FIELD

[0001] The present invention generally relates to a printed sheet inspection system. The invention is applicable in particular as an in-line inspection system in a sheet-fed printing press, especially in a sheet-fed intaglio printing press.

BACKGROUND OF THE INVENTION

[0002] Sheet inspection systems are known as such in the art, in particular for the purpose of carrying out in-line inspection on sheet-fed intaglio printing presses. Sheet-fed intaglio printing presses and sheet inspection systems therefor are for instance disclosed in International (PCT) Publications Nos. WO 03/070465 A1, WO 2007/060615 A1, WO 2011/077348 A1, WO 2011/077350 A1, WO 2011/077351 A1, WO 2011/161656 A1, European Patent Publications Nos. EP 0 527 453 A1, EP 1 190 855 A1, EP 1 231 057 A1, EP 1 808 391 A1, EP 2 230 202 A2, EP 2 586 612 A1, EP 2 687 839 A2 and Japanese Patent Publications Nos. JP 2012-061602 A, JP 2015-105846 A.

[0003] The known solutions typically make use of so-called CCD (Charge Couple Device) image sensors which are located at a distance from the printed sheet to be inspected. In some instances (see e.g. EP 0 527 453 A1, EP 1 190 855 A1, EP 1 231 057 A1, EP 1 808 391 A1, WO 03/070465 A1, WO 2007/060615 A1, WO 2011/077348 A1, WO 2011/077350 A1, WO 2011/077351 A1), the inspection system includes a CCD array sensor and is configured to take a snapshot of the entire surface of the printed sheet or of different portions of the printed sheet. In other instances (see e.g. EP 2 230 202 A2, EP 2 586 612 A1, EP 2 687 839 A2, JP 2012-061602 A, JP 2015-105846 A, WO 2011/161656 A1), the inspection system includes a CCD line sensor and is configured to scan the printed sheet as it moves past the sensor so as to acquire an image of the full printed sheet.

[0004] The printed sheet to be inspected is typically supported during the image acquisition process against a reference surface, which can be flat or curved depending on the application. In some instances, this is achieved by drawing the printed sheet against the reference surface by suction of the opposite side of the printed sheet, which requires a suitable suction system located along the transport path of the printed sheets (see e.g. EP 0 527 453 A1, EP 1 190 855 A1, EP 1 231 057 A1, EP 1 808 391 A1, EP 2 230 202 A2, WO 03/070465 A1, WO 2011/161656 A1). Alternatively, or in addition to the above measures, air nozzles and/or air blades may be provided in order to blow air against the printed surface of the printed sheet to be inspected to press it against the reference surface (see e.g. EP 2 230 202 A2, EP 2 586 612 A1, WO 2011/161656 A1).

[0005] Suction of the opposite side of the printed sheet is not, however, always possible, especially when inspection is being carried out while the printed sheet to be inspected is still being transported by an impression cylinder of a printing group of the sheet-fed printing press, away from the printing nip (see e.g. EP 2 586 612 A1, EP 2 687 839 A2, JP 2012-061602 A, JP 2015-105846 A). In that case, air nozzles and/or air blades are typically contemplated in an attempt to press the sheet to be inspected against the circumferential surface of the impression cylinder (see also e.g. International (PCT) Publication No. WO 2005/108082 A1 and European Patent Publication No. EP 1 958 772 A2).

[0006] Air nozzles and air blades are typically supplied with compressed air and are positioned to blow air directly against the sheet surface and locally generate air pressure to maintain the sheet against the circumferential surface of the cylinder transporting the sheet, which circumferential surface acts as reference surface. Air nozzles and air blades have a fundamental problem in that they generate highly turbulent airflow and typically require multiple nozzles or air blades, which need to be positioned individually, with a specific adjustment of the airflow. These solutions therefore become unnecessarily complex and difficult to adjust in practice.

[0007] So-called contact image sensors (CIS) are also known in the art and are typically used in flatbed scanners. They usually consist of a linear array of image detectors covered by individual focussing lenses and flanked by LEDs for illumination purposes. They are located almost in direct contact with the object to be imagined. CIS devices are much smaller than CCD sensors and use much less power.

[0008] The focal length of CIS devices (which may be of the order of 10 to 60 mm) is substantially shorter than that of CCD devices, hence the reason why they need to be located close to the surface of the object to be imaged. At first sight, this constitutes a limitation with respect to the use of CIS devices as imaging devices for inspecting printed sheets in sheet-fed printing presses. Indeed, the very short focal length of CIS devices necessarily imposes very stringent requirements as regards transport and guidance of the printed sheets past the imaging device to avoid mechanical interference between the printed sheets and the imaging system, which could cause print quality issues.

[0009] From a practical point of view, and as far as the inspection of printed material is concerned, CIS devices have therefore mainly been used in web-fed printing presses, as transport and guidance of the printed web is far easier to control.

[0010] This being said, it has already been suggested in the art to use CIS devices for the purpose of inspecting printed sheets in sheet-fed printing presses. International (PCT) Publication No. WO 2006/046249 A1 for instance discloses such a solution. To the best of the Applicant's knowledge, such solution has not been successfully put into practice, however, presumably because the printed

sheets are allowed to move and flap as they pass through and leave the printing nip of the printing group, which would inevitably cause print quality issues. Indeed, no particular measure is disclosed in International (PCT) Publication No. WO 2006/046249 A1 that would prevent the printed sheets from touching the frame or other components of the inspection system, which sits very close to the transport path of the printed sheets. This problem is exacerbated by the fact that the printed sheets also have a tendency to stick to the surface of the printing cylinder that transfers ink to the surface of the sheets, be it a plate cylinder that transfers ink directly to the surface of the sheets or a blanket cylinder that collects ink from one or more upstream-located plate cylinders before transfer thereof to the surface of the sheets.

[0011] There is therefore a need for an improved solution that remedies the above-noted shortcomings of the prior art.

SUMMARY OF THE INVENTION

[0012] A general aim of the invention is to provide an improved sheet inspection system.

[0013] More specifically, an aim of the present invention is to provide such a sheet inspection system that ensures that the printed sheets to be inspected are properly supported against the circumferential surface of the cylinder transporting the printed sheets past the imaging unit.

[0014] Yet another aim of the invention is to provide such a solution which prevents the occurrence of print quality issues on the printed sheets being inspected.

[0015] A further aim of the invention is to provide such a solution which makes it possible to use contact image sensors as the image sensor of the imaging unit.

[0016] Still another aim of the invention is to provide such a solution that less complex than the known solutions and that is easier to operate and maintain.

[0017] These aims are achieved thanks to the solutions defined in the claims.

[0018] In accordance with the invention, there is provided a sheet inspection system according to claim 1, namely a sheet inspection system configured to inspect printed sheets being transported by a transport cylinder of a sheet-fed printing press, which printed sheet inspection system comprises an imaging unit located proximate to a circumferential surface of the transport cylinder, which imaging unit is configured to acquire an image of a printed surface of the printed sheet as the printed sheet moves past the imaging unit under the action of the transport cylinder. According to the invention, the sheet inspection system further comprises a blowing unit coupled to an air diffuser, which air diffuser is positioned proximate to the circumferential surface of the transport cylinder and extends along a portion of the circumferential surface of the transport cylinder, the blowing unit and air diffuser being configured to produce an air pressure zone and form an air cushion zone, laterally containing the air pressure zone, which press the printed sheet against the circumferential surface of the transport cylinder.

[0019] Preferably, a lower side of the air diffuser, which is positioned proximate to the circumferential surface of the transport cylinder, is provided with a diffuser opening that extends both in the lateral and circumferential directions, which diffuser opening faces the circumferential surface of the transport cylinder, and the air pressure zone and air cushion zone coincide with a shape and position of the diffuser opening. In this context, a width of the diffuser opening, transversely to a transport path of the printed sheets, may especially be of the order of 800 mm. The diffuser opening may in particular be substantially rectangular.

[0020] In this context, the air diffuser may further be provided with two lateral surfaces extending in the circumferential direction, on either side of the diffuser opening, each lateral surface contributing to the formation of a corresponding air cushion which contains the air pressure zone between the thus created air cushion zone, a width of each lateral surface being comparatively larger than a gap between the lower side of the air diffuser and the circumferential surface of the transport cylinder.

[0021] A gap between a lower side of the air diffuser and the circumferential surface of the transport cylinder may especially be of less than 5 mm, which favours production of the air pressure zone and formation of the air cushion zone.

[0022] In accordance with a particularly preferred embodiment of the invention, the imaging unit is located inside an inner space of the air diffuser. In particular, the imaging unit may be located in an inlet section of the air diffuser. In this latter context, the imaging unit may be located in the inlet section of the air diffuser so as to cause a breakpoint of the airflow upstream of a trailing edge zone of the air diffuser and downstream of the imaging unit.

[0023] By way of preference, the imaging unit comprises a contact image sensor (CIS), the focal length of which may be of less than 100 mm, in particular of the order of 60 mm or less. Other types of image sensors, including CCD image sensors, could still be contemplated, however.

[0024] In accordance with an embodiment of the invention, the air diffuser comprises an arc-shaped leading end section that extends from an inlet section of the air diffuser along the portion of the circumferential surface of the transport cylinder.

[0025] Furthermore, the air diffuser may be configured such as to produce a high-velocity air jet exiting a leading edge of the air diffuser in a direction opposite to a transport direction of the printed sheet.

[0026] By way of preference, the air diffuser is configured such that airflow velocity of the air exiting edges of the air diffuser is greater than airflow velocity inside the air diffuser, pressure inside the air diffuser being greater than ambient pressure.

[0027] In accordance with yet another preferred em-

bodiment of the invention, the air diffuser is configured to subject the printed sheet to both a shear force, having a main component extending in a direction opposite to a direction of transport of the printed sheet, and a pressure force, perpendicular to the printed surface of the printed sheet.

[0028] Advantageously, the air diffuser may comprise an adjustable blade located at a trailing end of the air diffuser to adjust a gap between a trailing edge of the air diffuser and the printed surface of the printed sheet exiting the air diffuser.

[0029] The blowing unit may especially be a high-pressure centrifugal fan. Furthermore, the blowing unit is preferably provided with a fine filter.

[0030] Also claimed is a sheet-fed printing press comprising a printing group including at least an impression cylinder and a printing cylinder cooperating with the impression cylinder to form a printing nip therebetween, wherein the sheet-fed printing press further comprises a printed sheet inspection system in accordance with the invention to carry out in-line inspection of the printed sheets that are printed on the sheet-fed printing press. In this case, the impression cylinder acts as the transport cylinder of the printed sheet inspection system, and the imaging unit and the air diffuser are located downstream of the printing nip.

[0031] By way of preference, the sheet-fed printing press is an intaglio printing press comprising an intaglio plate cylinder acting as the printing cylinder.

[0032] Further advantageous embodiments of the invention are discussed below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] Other features and advantages of the present invention will appear more clearly from reading the following detailed description of embodiments of the invention which are presented solely by way of non-restrictive examples and illustrated by the attached drawings in which:

Figure 1 is a schematic perspective view of a printed sheet inspection system in accordance with an embodiment of the present invention, which printed sheet inspection system is shown in association with an impression cylinder and a printing cylinder of a printing group of an intaglio printing press;

Figure 2 is a schematic cross-sectional side view of the printed sheet inspection system of Figure 1;

Figure 3 is a schematic perspective view of the printed sheet inspection system of Figure 1 as viewed from a different viewing angle, which printed sheet inspection system is shown in association with the impression cylinder;

Figure 4 is another schematic perspective view of the printed sheet inspection system of Figure 1 as viewed from an opposite direction compared to Figure 3, with the impression cylinder removed;

Figure 5 is a partial cross-sectional side view of an air diffuser of the sheet inspection system of Figure 1; and

Figure 5A is an enlarged view of a trailing end section of the air diffuser of Figure 5.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0034] The present invention will be described in relation to various illustrative embodiments. It shall be understood that the scope of the invention encompasses all combinations and sub-combinations of the features of the embodiments disclosed herein.

[0035] As described herein, when two or more parts or components are described as being connected, secured or coupled to one another, they can be so connected, secured or coupled directly to each other or through one or more intermediary parts.

[0036] The invention will be described in relation to various embodiments of a printed sheet inspection system, as depicted in the appended Figures. These embodiments are disclosed in the particular context of an integration into a sheet-fed intaglio printing press as commonly used for the production of security documents, such as banknotes. It should however be appreciated that the printed sheet inspection system of the invention could be used in connection with and be integrated into any other type of sheet-fed printing press, including but not limited to offset printing presses, silk-screen printing presses, and letterpress printing presses.

[0037] Figure 1 is a schematic perspective view of a printed sheet inspection system in accordance with an embodiment of the present invention, which printed sheet inspection system is shown in association with an impression cylinder 6 and an intaglio plate cylinder 8 of a printing group of an intaglio printing press. Other components of the intaglio printing press have been omitted for the sake of simplicity, but it should be appreciated that the intaglio printing press typically further comprises an inking system designed to ink the intaglio printing plates that are carried by the intaglio plate cylinder, a wiping system designed to wipe excess ink from the surface of the intaglio printing plates, a sheet feeder system to supply printed sheets to the impression cylinder 6, as well as a sheet delivery system to transport the printed sheets away from the impression cylinder 6. These other components are not of direct relevance for the invention and do not need to be described here. As far as the configuration of the intaglio printing press is concerned, reference can be made to the various patent publications mentioned in the preamble hereof.

[0038] As is typical in the art, the impression cylinder 6 is provided with a set of sheet grippers 7 that are designed to hold the printed sheets 1 by a leading edge thereof, as schematically shown in Figure 1. These sheet grippers are located in corresponding cylinder pits that are distributed about the circumference of the impression

cylinder. Cylinder pits are likewise provided on the intaglio plate cylinder 8 to house plate clamping systems (not shown) to clamp the leading and trailing ends of the intaglio printing plates (not shown).

[0039] In the context of the illustrated embodiment, it should be appreciated that the impression cylinder 6 acts as transport cylinder to transport the printed sheets 1 past an imaging unit 4 (not shown in Figure 1 but visible in Figures 2 and 5) of the printed sheet inspection system. The intaglio plate cylinder 8 here acts as printing cylinder transferring ink to one surface of the printed sheets 1, namely the lower side thereof, which surface is to be inspected by the printed sheet inspection system. The printed sheets 1 are printed at the printing nip formed between the impression cylinder 6 and the intaglio plate cylinder 8 (see also Figure 2).

[0040] Figure 2 is a schematic cross-sectional side view of the printed sheet inspection system of Figure 1, also showing the aforementioned impression cylinder 6 and intaglio plate cylinder 8. In the illustrated example, it is readily apparent that the impression cylinder 6 and intaglio plate cylinder 8 are both three-segment cylinders, each comprising three cylinder pits that are distributed evenly about the circumference of the cylinder. Also visible in Figure 2 are three sets of sheet grippers 7 located in the cylinder pits of the impression cylinder 6, each designed to hold a printed sheet by a leading edge.

[0041] Figure 3 is a schematic perspective view of the printed sheet inspection system of Figure 1 as viewed from a different viewing angle, which printed sheet inspection system is shown in association with the impression cylinder 6. The intaglio plate cylinder 8 has been omitted in this view to more clearly illustrate the invention. Figure 4 is another schematic perspective view of the printed sheet inspection system of Figure 1 as viewed from an opposite direction compared to Figure 3, with the impression cylinder 6 removed.

[0042] Key components of the printed sheet inspection system are shown in Figures 1 to 4, including the imaging unit 4 that is located proximate to a circumferential surface of the impression cylinder 6, which imaging unit 4 is configured to acquire an image of the printed surface of the printed sheet 1 as the printed sheet 1 moves past the imaging unit 4 under the action of the impression cylinder 6 (the impression cylinder 6 rotating in the clockwise direction in Figure 2 during printing operations).

[0043] The printed sheet inspection system further comprises a blowing unit 5 that is coupled to an air diffuser 2, which air diffuser 2 is positioned proximate to the circumferential surface of the impression cylinder 6 and extends along a portion of the circumferential surface of the impression cylinder 6, downstream of the printing nip formed by the impression cylinder 6 and the intaglio plate cylinder 8. The blowing unit 5 and air diffuser 2 are configured to produce an air pressure zone and form an air cushion zone, laterally containing the air pressure zone, which press the printed sheet 1 against the circumferential surface of the impression cylinder 6.

[0044] As shown in Figure 4, a lower side of the air diffuser 2, which is positioned proximate to the circumferential surface of the impression cylinder 6, is provided with a diffuser opening that extends both in the lateral and circumferential directions, which diffuser opening faces the circumferential surface of the impression cylinder 6. The diffuser opening is here designed as a substantially rectangular opening. As schematically illustrated, an air pressure zone Z7 and an air cushion zone Z6, laterally containing the air pressure zone Z7, are thus created, which coincide with a shape and position of the, here substantially rectangular, diffuser opening. In that respect, a width of the diffuser opening, transversely to the transport path of the printed sheet 1, substantially corresponds to a maximum width of the printed sheet 1. A width of the order of 800 mm especially comes under consideration.

[0045] By way of preference, a gap between the lower side of the air diffuser 2 and the circumferential surface of the impression cylinder 6 is selected not to exceed a few millimetres, and may in particular be less than 5 mm. A gap of the order of 2 to 3 mm especially comes under consideration. This ensures that the air pressure zone Z7 and air cushion zone Z6 can suitably be produced and maintained.

[0046] In the illustrated, preferred embodiment, the imaging unit 4 is located inside an inner space of the air diffuser 2, as this is clearly visible in Figure 2, which constitutes a key advantage in that the imaging unit 4 is basically sealed from the environment by the air diffuser 2 and the airflow circulating therein. This further contributes to cooling the imaging unit 4. In other embodiments, the imaging unit 4 could however be located outside of the air diffuser 2 so as not to sit in the airflow produced by the air diffuser 2. In that respect, the air diffuser could especially be provided with a sealed window portion configured to allow the imaging unit to look at a portion of the printed sheet located within the air pressure zone created by the air diffuser.

[0047] Referring to the illustrated embodiment, the imaging unit 4 is advantageously located in an inlet section (Z1 in Figure 5) of the air diffuser 2. As this will be appreciated hereafter, this particular location of the imaging unit 4 is contemplated to cause a breakpoint of the airflow upstream of a trailing edge zone of the air diffuser 2 (see Figure 5).

[0048] By way of preference, the imaging unit 4 comprises a contact image sensor (CIS), and is therefore positioned in close proximity to the circumferential surface of the impression cylinder 6. In that regard, the focal length of the contact image sensor (CIS) is preferably of less than 100 mm, even more preferably of the order of 60 mm or less. A focal length as low as 10 mm could for instance be contemplated in the context of the present invention. This considerably reduces overall dimensions of the printed sheet inspection system as compared to the known solutions making use of CCD image sensor devices.

[0049] Advantageously, the imaging unit 4 could be supported inside the air diffuser 2 in such a way as to allow adjustment of the position of the imaging unit 4 with respect to the circumference of the impression cylinder 6, thereby allowing to carry out adjustment of the focus of the imaging unit 4 with respect to the printed sheets 1 to be inspected. A motorized adjustment system especially comes under consideration.

[0050] According to the preferred embodiment shown in Figures 1 to 4, the air diffuser 2 advantageously comprises an arc-shaped leading end section that extends from the inlet section of the air diffuser 2, where the imaging unit 4 is preferably located, along the portion of the circumferential surface of the impression cylinder 6, towards the printing nip. More specifically, the air diffuser 2 is configured in such a way as to cause acceleration of the airflow in the leading end section of the air diffuser 2. Furthermore, the air diffuser 2 is here configured such that airflow velocity of the air exiting edges of the air diffuser 2 is greater than airflow velocity inside the air diffuser, pressure inside the air diffuser 2 being greater than ambient pressure.

[0051] The aforementioned blowing unit 5 is here a high-pressure centrifugal fan. Other solutions could be contemplated to provide the air diffuser 2 with a suitable air supply, but a high-pressure centrifugal fan is a particularly advantageous and compact solution. Indeed, as shown in the Figures, the high-pressure centrifugal fan, acting as blowing unit 5, can simply be connected to a rear end of the air diffuser 2, at the inlet section, via a suitable conduit. In that respect, cables and connections to the imaging unit 4 could conveniently be routed via the conduit connecting the blowing unit 5 to the air diffuser 2.

[0052] Advantageously, airflow produced by the blowing unit 5 is adjustable.

[0053] Furthermore, the blowing unit 5 is preferably provided with a fine filter to ensure a higher air purity and prevent ambient dust from being projected against the freshly-printed side of the printed sheet 1. In the context of the illustrated embodiment, the provision of a fine filter will further protect the imaging unit 4 from dust projection and contamination coming from the printed sheets and from the printing press environment.

[0054] Thanks to the aforementioned air diffuser 2, a defined air pressure zone Z7 is thus created over the relevant portion of the circumferential surface of the impression cylinder 6, and therefore over the relevant portion of the printed sheets 1 being transported through the gap between the air diffuser 2 and the circumferential surface of the impression cylinder 6, which causes the printed sheet 1 to be pressed against the circumferential surface of the impression cylinder 6. Furthermore, an air cushion zone Z6, laterally containing the air pressure zone Z7, is formed along the sides of the air diffuser 2. This air cushion zone Z6 maintains the air pressure zone Z7 within the limits of the printed sheet 1 to be inspected, thereby ensuring that air pressure is only applied where it needs to.

[0055] By way of preference, a suitable air cushion zone Z6 is created on both lateral sides of the air diffuser 2 by the provision of two lateral surfaces extending in the circumferential direction, on either side of the diffuser opening (as for instance shown in Figure 4), each lateral surface contributing to the formation of a corresponding air cushion which contains the air pressure zone Z7 between the thus created air cushion zone Z6. The width of each lateral surface (which by way of illustration can be of the order of 140 mm) is comparatively larger than the gap between the said lateral surfaces and the circumferential surface of the impression cylinder 6 (which by way of illustration can be of the order of 2 to 3 mm).

[0056] One will appreciate that air is allowed to flow from the air pressure zone Z7 via the side edges and leading edge of the air diffuser 2, with airflow components extending both in the lateral and circumferential directions away from the air diffuser 2. This inherently leads to a flattening of the printed sheet 1 lying under the air diffuser 2 against the circumference of the impression cylinder 6. This divergent airflow, exhibiting both lateral and circumferential components, is also favourable in that it helps ensuring an adequate flattening of the printed sheet 1 lying under the air diffuser 2, even for small-format sheets, as the flattening effect occurs from the centre of the printed sheet 1 towards the sides and the trailing end of the sheet. This further prevents air from going underneath the printed sheet 1, which could otherwise lead to separation from the circumferential surface of the impression cylinder 6.

[0057] Figure 5 is a partial cross-sectional side view of the air diffuser 2 of the sheet inspection system of Figure 1. Figure 5 in particular shows that the imaging unit 4 is located in the inlet section Z1 of the air diffuser 2, closer to a lower wall of the inlet section Z1, to force part of the inlet airflow above the imaging unit 4 and to cause a breakpoint of the airflow at Z2, upstream of a trailing edge zone Z5 of the air diffuser 2 and downstream of the imaging unit 4. As a consequence, a small part of the air flux flows out at Z5, and the other part of the air flux passes in front of the imaging unit 4. The location Z2 where the breakpoint occurs is preferably such as to be close to the trailing edge zone Z5 in order to minimize interference with the trailing edge of the printed sheet 1 upon leaving the air diffuser 2. The external geometry of the imaging unit 4, which sits in the passage of the air, could be optimized to improve airflow in the inlet section Z1, around the imaging unit 4, and downstream thereof.

[0058] Air is introduced at the inlet section Z1 of the air diffuser 2, at low speed V1, under the action of the blowing unit 5. As already mentioned, the configuration of the air diffuser 2 is such that airflow velocity V2 in the arc-shaped leading end section of the air diffuser 2 (zone Z3) is greater than airflow velocity V1 at the inlet section Z1 of the air diffuser 2. Furthermore, the configuration of the air diffuser 2 is such that a high-velocity air jet is produced at Z4, exiting a leading edge of the air diffuser 2 in a direction opposite to a transport direction of the printed

sheet 1. This prevents the printed sheet 1 from coming off the impression cylinder 6 prior to entering the gap between the air diffuser 2 and the circumferential surface of the impression cylinder 6. The velocity V3 of the air jet produced at Z4, as well as of the air flowing off the sides of the air diffuser 2, is higher than the airflow velocity V2 in zone Z3, making the pressure inside the air diffuser 2 higher than ambient pressure, contributing to the formation of the air pressure zone Z7 and air cushion zone Z6.

[0059] The system is designed so that the airflow velocities V2 and V3 are much higher (10 times or more) than the transport velocity VR of the printed sheets 1 induced by rotation of the impression cylinder 6. By way of illustration, the air diffuser 2 can be designed to achieve airflow velocities V2 and V3 of the order of 10-15 m/s and more than 30 m/s, respectively.

[0060] The aforementioned measures contribute to producing a pressure force P1, perpendicular to the surface of the printed sheet 1, which presses the printed sheet 1 against the circumferential surface of the impression cylinder 6, as well as a shear force S1, created by the air friction on the sheet surface, which shear force S1 has a main component extending in a direction opposite to the direction of transport of the printed sheet 1. Preferably, the ratio S1/P1, which is equivalent to a friction coefficient, is selected to be less than 2%, which is much lower than the friction coefficient between the printed sheet 1 and the impression cylinder 6.

[0061] Figure 5A is an enlarged view of a trailing end section of the air diffuser 2 shown in Figure 5. It illustrates a further refinement of the invention, namely the additional provision of an adjustable blade 3 located at the trailing end of the air diffuser 2 to adjust a gap between the trailing edge of the air diffuser 2 and the printed surface of the printed sheet 1 exiting the air diffuser 2. This blade 3 can be adjusted to make the gap at the trailing edge as small as possible to reduce the flow of air coming off the trailing end of the air diffuser 2. This will help preventing the printed sheet 1 exiting the air diffuser 2 from being pushed away.

[0062] Various modifications and/or improvements may be made to the above-described embodiments without departing from the scope of the invention as defined by the appended claims. In particular, the invention is not only applicable as an in-line inspection system in an intaglio printing press, but could possibly be used in other types of printing presses.

[0063] Furthermore, while a contact image sensor (CIS) is preferably contemplated to be used for the purpose of acquiring an image of the printed sheet to be inspected, other types of image sensors could be used. For instance, CCD image sensors could still be contemplated, provided a position of the imaging unit is adjusted accordingly.

[0064] Moreover, the imaging unit does not necessarily need to be located in the path of the airflow. The imaging unit could for instance be located outside of the inner chamber of the air diffuser. In that respect, the air diffuser could for instance be provided with a sealed window portion configured to allow the imaging unit to look at a portion of the printed sheet located within the air pressure zone created by the air diffuser.

LIST OF REFERENCE NUMERALS AND SIGNS USED THEREIN

[0065]

1	printed sheet (e.g. sheet carrying printing security imprints)
2	air diffuser
3	adjustable blade at trailing end of air diffuser 2
4	imaging unit, e.g. contact image sensor (CIS)
5	blowing unit, e.g. high-pressure centrifugal fan
6	transport cylinder (e.g. impression cylinder of intaglio printing press)
7	sheet grippers designed to hold leading edge of printed sheet 1
8	printing cylinder (e.g. intaglio plate cylinder of intaglio printing press)
P1	pressure force produced by air diffuser 2 (perpendicularly to surface of printed sheet 1)
S1	shear force produced by air diffuser 2 (tangentially to surface of printed sheet)
V1	airflow velocity at inlet section Z1
V2	airflow velocity in middle zone Z3
V3	airflow velocity at leading edge zone Z4
VR	rotational speed of transport cylinder 6 / transport velocity of printed sheet 1
Z1	inlet section of air diffuser 2
Z2	breakpoint zone of inlet airflow close to trailing edge zone Z5
Z3	middle zone of air diffuser 2 (upstream of the position of the imaging unit 4)
Z4	leading edge zone of air diffuser 2 (entry zone of printed sheet 1)
Z5	trailing edge zone of air diffuser 2 (exit zone of printed sheet 1)
Z6	air cushion zone along sides of air diffuser 2
Z7	air pressure zone created by air diffuser 2

Claims

1. A printed sheet inspection system configured to inspect printed sheets (1) being transported by a transport cylinder (6) of a sheet-fed printing press, which printed sheet inspection system comprises an imaging unit (4) located proximate to a circumferential surface of the transport cylinder (6), which imaging unit (4) is configured to acquire an image of a printed surface of the printed sheet (1) as the printed sheet (1) moves past the imaging unit (4) under the action of the transport cylinder (6),
characterized in that the sheet inspection system further comprises a blowing unit (5) coupled to an

air diffuser (2), which air diffuser (2) is positioned proximate to the circumferential surface of the transport cylinder (6) and extends along a portion of the circumferential surface of the transport cylinder (6), the blowing unit (5) and air diffuser (2) being configured to produce an air pressure zone (Z7) and form an air cushion zone (Z6), laterally containing the air pressure zone (Z7), which press the printed sheet (1) against the circumferential surface of the transport cylinder (6).

2. The printed sheet inspection system according to claim 1, wherein a lower side of the air diffuser (2), which is positioned proximate to the circumferential surface of the transport cylinder (6), is provided with a diffuser opening that extends both in the lateral and circumferential directions, which diffuser opening faces the circumferential surface of the transport cylinder (6), and wherein the air pressure zone (Z7) and air cushion zone (Z6) coincide with a shape and position of the diffuser opening,
a width of the diffuser opening, transversely to a transport path of the printed sheets (1), being preferably of the order of 800 mm.

3. The printed sheet inspection system according to claim 2, wherein the air diffuser (2) is further provided with two lateral surfaces extending in the circumferential direction, on either side of the diffuser opening, each lateral surface contributing to the formation of a corresponding air cushion which contains the air pressure zone (Z7) between the thus created air cushion zone (Z6),
and wherein a width of each lateral surface is comparatively larger than a gap between the lower side of the air diffuser (2) and the circumferential surface of the transport cylinder (6).

4. The printed sheet inspection system according to any one of the preceding claims, wherein a gap between a lower side of the air diffuser (2) and the circumferential surface of the transport cylinder (6) is of less than 5 mm.

5. The printed sheet inspection system according to any one of the preceding claims, wherein the imaging unit (4) is located inside an inner space of the air diffuser (2).

6. The printed sheet inspection system according to claim 5, wherein the imaging unit (4) is located in an inlet section (Z1) of the air diffuser (2).

7. The printed sheet inspection system according to claim 6, wherein the imaging unit (4) is located in the inlet section (Z1) of the air diffuser (2) so as to cause a breakpoint of the airflow upstream of a trailing edge zone (Z5) of the air diffuser (2) and downstream of the imaging unit (4).

8. The printed sheet inspection system according to any one of the preceding claims, wherein the imaging unit (4) comprises a contact image sensor (CIS),
and wherein a focal length of the contact image sensor (CIS) is preferably of less than 100 mm, in particular of the order of 60 mm or less.

9. The printed sheet inspection system according to any one of the preceding claims, wherein the air diffuser (2) comprises an arc-shaped leading end section that extends from an inlet section (Z1) of the air diffuser (2) along the portion of the circumferential surface of the transport cylinder (6).

10. The printed sheet inspection system according to any one of the preceding claims, wherein the air diffuser (2) is configured such as to produce a high-velocity air jet exiting a leading edge of the air diffuser (2) in a direction opposite to a transport direction of the printed sheet (1).

11. The printed sheet inspection system according to any one of the preceding claims, wherein the air diffuser (2) is configured such that airflow velocity (V3) of the air exiting edges of the air diffuser (2) is greater than airflow velocity (V2) inside the air diffuser (2), pressure inside the air diffuser (2) being greater than ambient pressure.

12. The printed sheet inspection system according to any one of the preceding claims, wherein the air diffuser (2) is configured to subject the printed sheet (1) to both a shear force (S1), having a main component extending in a direction opposite to a direction of transport of the printed sheet (1), and a pressure force (P1), perpendicular to the printed surface of the printed sheet (1).

13. The printed sheet inspection system according to any one of the preceding claims, wherein the air diffuser (2) comprises an adjustable blade (3) located at a trailing end of the air diffuser (2) to adjust a gap between a trailing edge of the air diffuser (2) and the printed surface of the printed sheet (1) exiting the air diffuser (2).

14. The printed sheet inspection system according to any one of the preceding claims, wherein the blowing unit (5) is a high-pressure centrifugal fan, and/or
wherein the blowing unit (5) is provided with a fine filter.

15. A sheet-fed printing press comprising a printing group including at least an impression cylinder (6) and a printing cylinder (8) cooperating with the impression cylinder (6) to form a printing nip therebe-

tween, **characterized in that** the sheet-fed printing press further comprises a printed sheet inspection system in accordance with any one of the preceding claims to carry out in-line inspection of the printed sheets (1) that are printed on the sheet-fed printing press,
wherein the impression cylinder (6) acts as the transport cylinder of the printed sheet inspection system,
wherein the imaging unit (4) and the air diffuser (2) are located downstream of the printing nip,
and wherein the sheet-fed printing press is preferably an intaglio printing press comprising an intaglio plate cylinder acting as the printing cylinder (8).

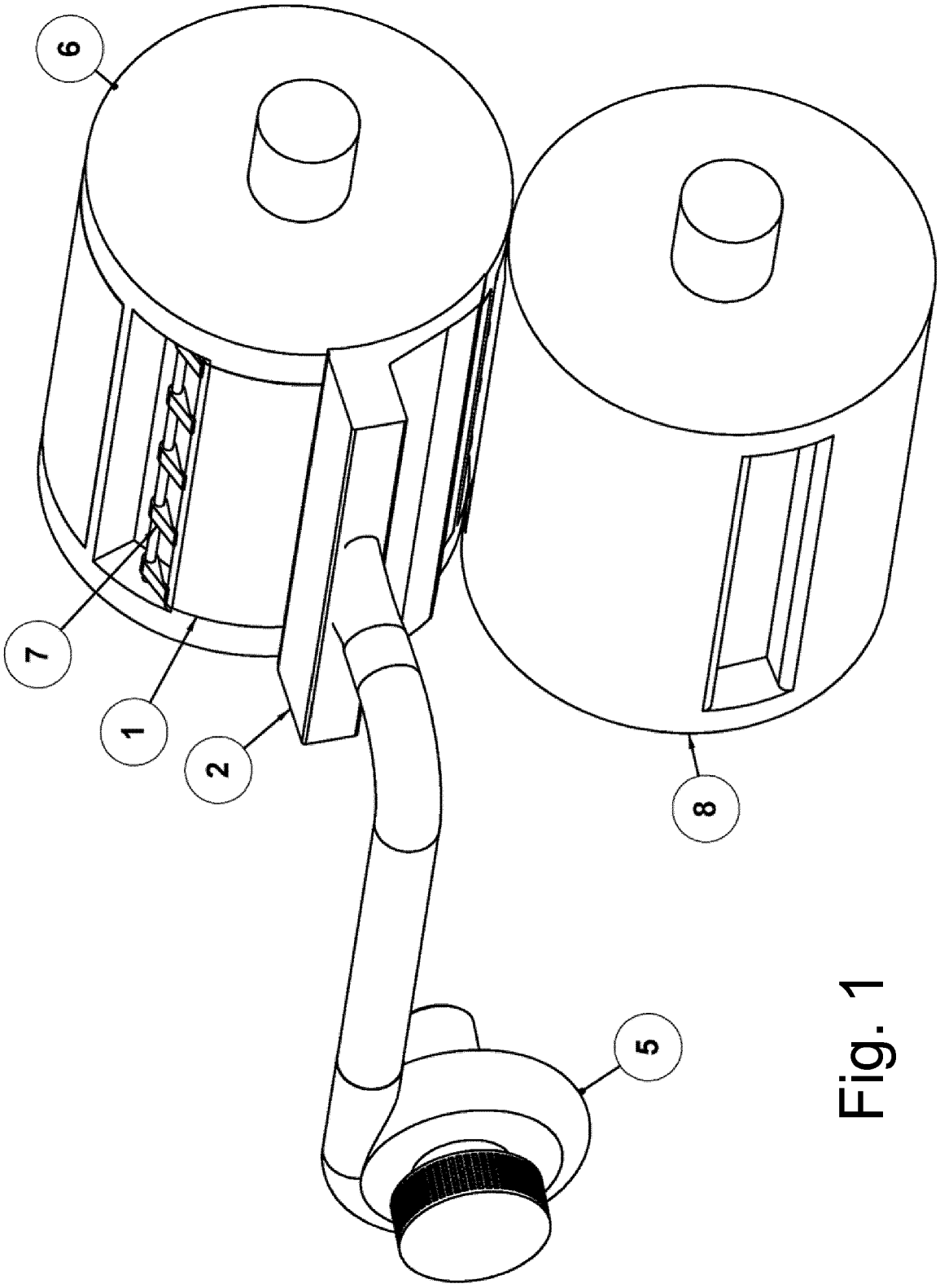

Fig. 1

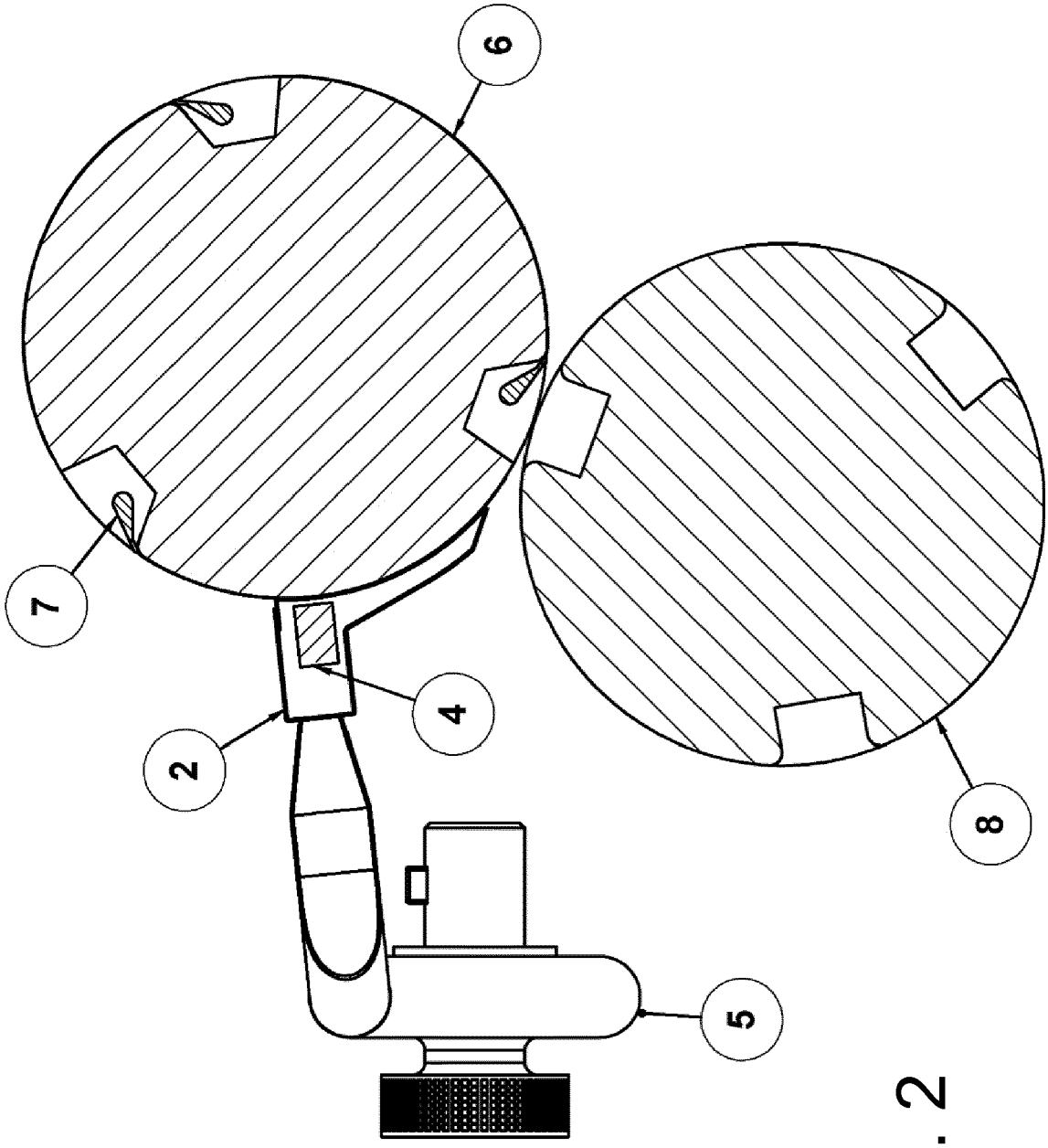

Fig. 2

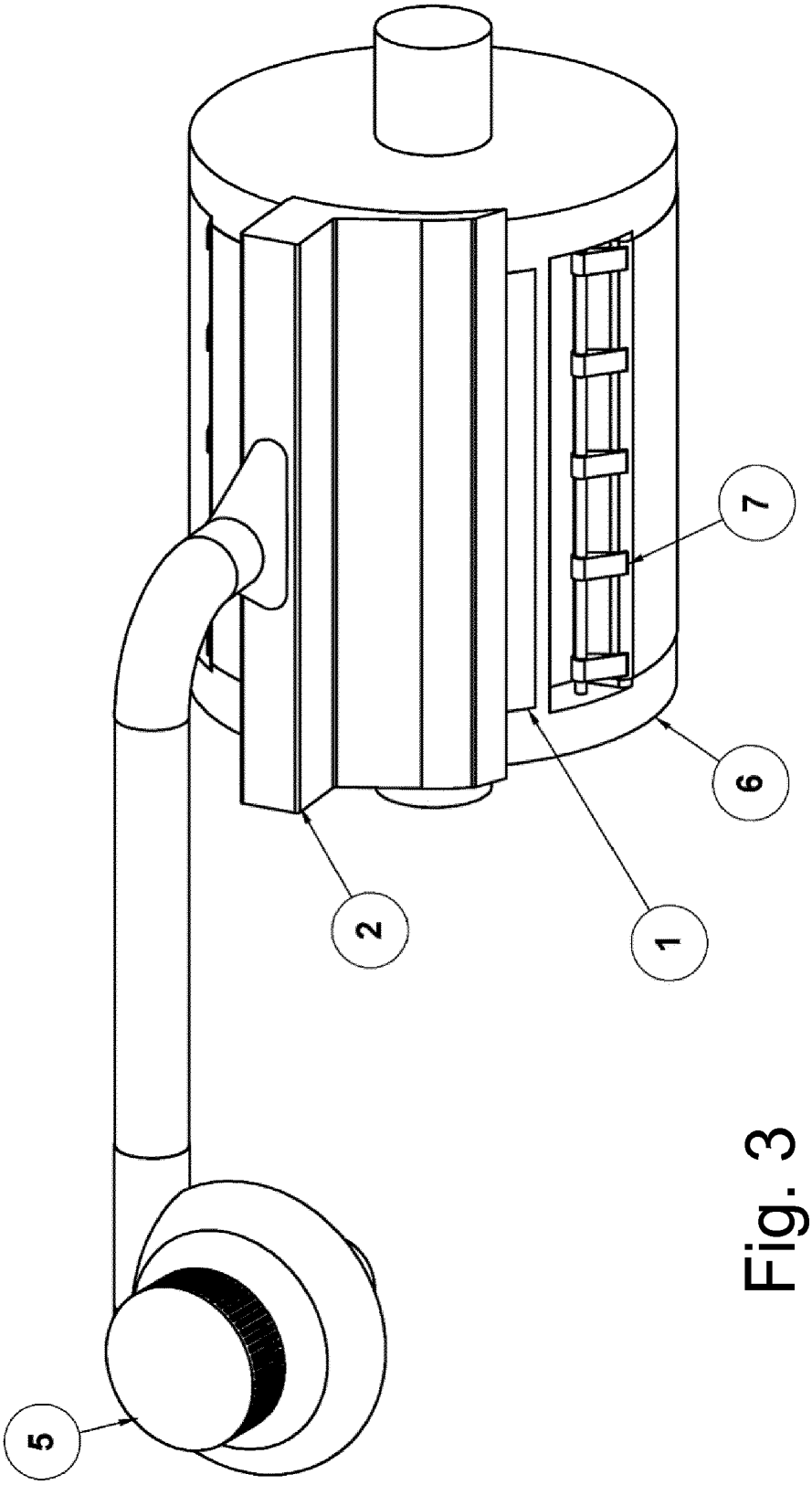

Fig. 3

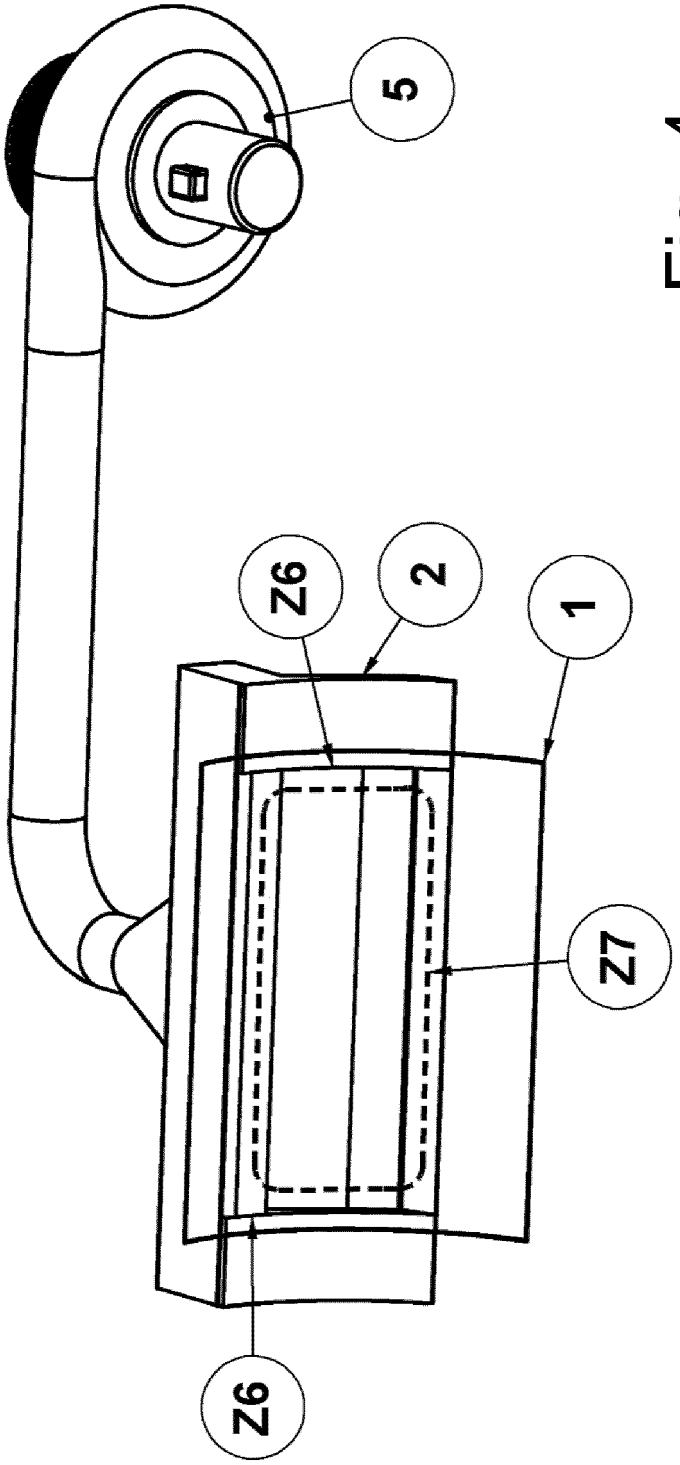

Fig. 4

Fig. 5A

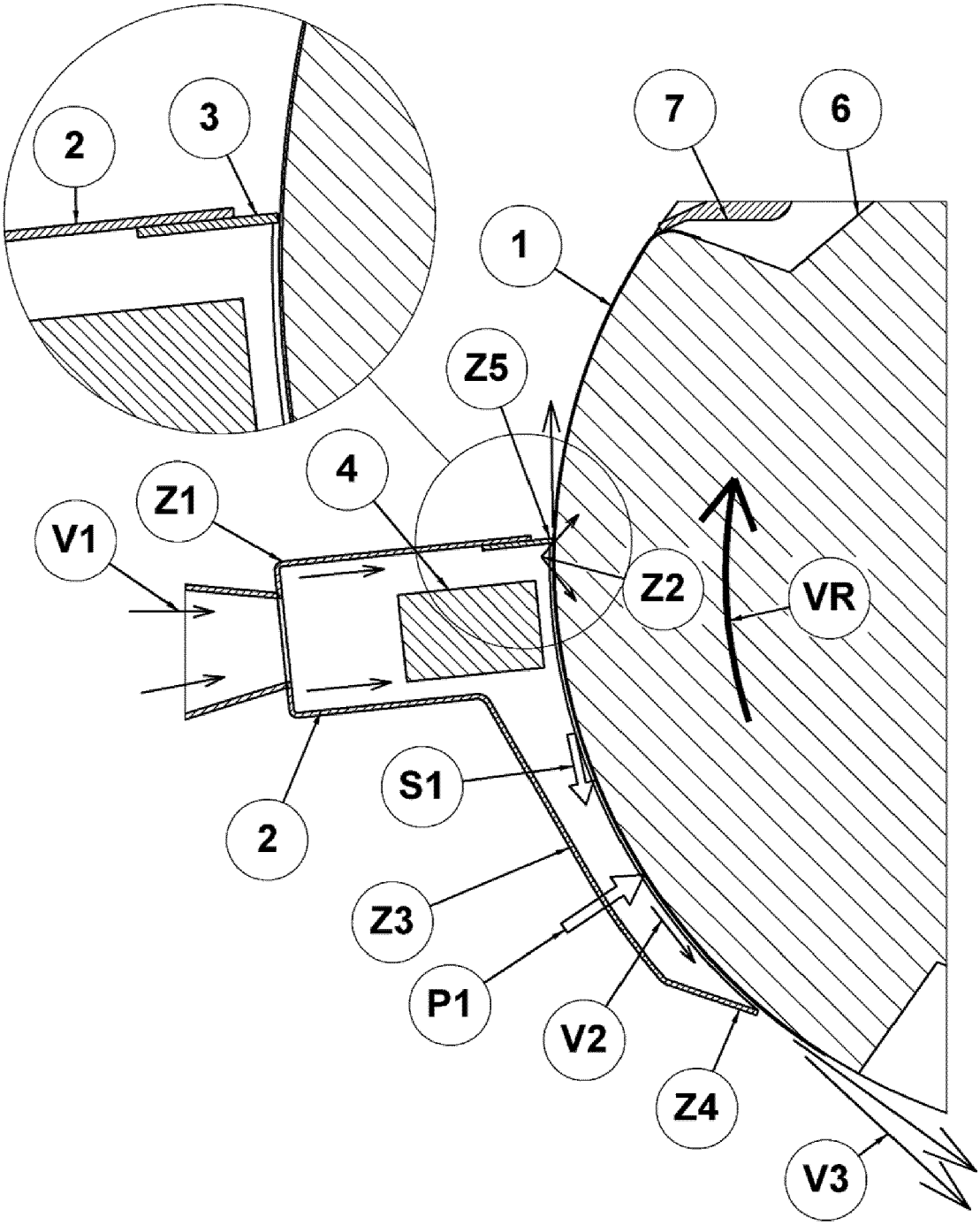

Fig. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 19 16 5187

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Place of search	Date of completion of the search	Examiner
Munich	2 July 2019	Hajji, Mohamed-Karim

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