Non-destructive testing ("NDT") device particularly for unmanned aerial vehicle ("UAV"), UAV and kit for NDT comprising the device

DESCRIPTION

TECHNICAL FIELD

The invention relates to a device for performing non-destructive testing (hereinafter also referred to as "NDT") of structures, particularly for an unmanned aerial vehicle (hereinafter also referred to as "UAV"), to a UAV and a kit for NDT comprising the NDT device.

BACKGROUND ART

Non-destructive testing of structures involves thoroughly examining a structure without harming it or requiring significant disassembly thereof. Various types of NDT sensors may be utilized to collect data regarding the structure from which internal flaws can be identified. The data acquired by the sensors is typically processed by a processing unit, and the processed data may be presented to a user via a display.

Among the structures that are routinely non-destructively tested, there are certain which pose significant challenges in testing, such as cargo holds, bridges, dams, offshore platforms, oil refineries, power plants, chemical processing plants, high rise buildings, just to name a few.

In-person human-based inspections of such structures can be time consuming, expensive, complicated and often dangerous for an individual to perform. Thus, a need exists in the industry to address such a problem.

A device for non-destructively checking structures and, for example, measuring the thicknesses of structures using an ultrasonic probe is known from WO2012/013878. The device comprises a drone, which is capable of hovering flight and which can preferably be manually and remotely piloted by an operator using a remote control, as well as an onboard measurement probe which is connected to the drone by connection means.

The connection means enable the measurement probe, in contact with a surface of a structure to be checked, to be positioned and temporarily immobilized while piloting the drone. However, during hovering of the drone, contact between the drone and the surface of the structure may become unstable, reducing the accuracy of measurements carried out with the probe.

A UAV suitable for providing a more stable contact in particular with a vertical wall is known from WO2019/050401. This UAV comprises a body and rotors, an arm end, a first leg end and a second leg end intersected by a front plane and adapted for

together contacting the wall at three spaced-apart positions. Advantageously, an inspection device, such as an ultrasonic sensor, may be attached to the arm and adapted for measuring a wall property.

The known aerial vehicles cited above are beneficial for inspecting locations that otherwise would be hard to reach for humans. However, inspections using such aerial vehicles are still complicated and time-consuming. A reason for such inadequacy is the difficulty to precisely position any measurement probe or sensor in the desired target location on the surface of the structure to be inspected.

A further limitation of these known aerial vehicles is that, in harsh environments, they may not withstand impacts with external objects without deterioration of the flight propulsion system.

An aerial vehicle suitable for withstanding collisions with the environment is known from WO2019/048439. This aerial vehicle includes an inner frame, an inner flight propulsion system mounted on the inner frame, an outer frame, a gimbal system comprising at least two rotational couplings coupling the inner propulsion system to the outer frame, a control system, a power source, and an outer frame actuation system configured to actively orient the outer frame with respect to the inner frame. Advantageously, the outer frame protects the components mounted in this known aerial vehicle from being damaged upon impact with external objects. However, it is evident that the outer frame rotational coupling and actuation systems inevitably increase the size and complexity of the aerial vehicle. On the contrary, it would be desirable to provide an aerial vehicle that is more compact, thereby facilitating access to narrow environments.

Besides the problems set out with reference to the prior art cited above, it should be noted that performing NDT on the surface of a structure may be further complicated by the presence of oxidation, rust, or contaminants such as general soiling, carbon, grease, etc. on the structure surface.

A method addressing such a problem is known from WO2019/190325. This method is especially adapted for inspecting and manipulating a beam at a lower side of a roof or deck, using a UAV. The UAV comprises an inspection tool for inspecting a portion of the beam, and a manipulation tool in the form of cleaning equipment for cleaning a portion of the beam. The method comprises, when the UAV is in a hanging position in which the UAV is supported on the beam: operating the cleaning equipment to clean a portion of the beam, positioning the inspection tool at the cleaned location of the beam, and inspecting said cleaned location using the inspection tool.

While this known solution is especially adapted for inspecting and manipulating a beam, it is evident that it is not optimal for inspecting structures that are different from a beam. Moreover, positioning the inspection tool at the cleaned location of the beam may be difficult and time consuming because it requires propelling the UAV along the longitudinal direction of the beam.

An aerial vehicle suitable for withstanding impacts with external objects without deterioration of its propulsion system or sensors is known from WO2023/079523. This UAV is capable of performing highly accurate NDT in precise locations of a wide range of structures without being limited by the spatial orientations of their surfaces, being able to maintain stable contact therewith.

This aerial vehicle comprises an outer protective cage, a propulsion system mounted inside the outer protective cage, and an arm with a first end attached to the outer protective cage, the arm being provided with an NDT device.

This NDT device has an NDT sensor mounted at a second end of the arm and a couplant dispensing nozzle arranged for delivering couplant onto the NDT sensor.

The couplant dispensing nozzle is provided with a plurality of couplant outlets arranged around the NDT sensor for delivering couplant between the NDT sensor and the surface of the structure to be tested thereby improving the transmission of measurements signal between them.

While this known solution is highly appreciated and performs well in testing structures using a contact sensor, it has been observed that the reliability of tests could be improved.

The expression “contact sensor” refers preferably to a sensor configured to perform testing by making direct or indirect contact between the sensor itself and the structure being tested.

ES2893048A1 discloses another example of a drone-based NDT system.

US2018/275103A1 discloses an ultrasound probe designed for bore inspection, equipped with an offcentring device. The offcentring device includes two elastically deformable strips connected to the ultrasound probe and configured to keep the emission head of the ultrasound probe pressed firmly against the wall of the bore that is to be inspected. However, this probe is limited to cylindrical bore geometries, which restricts its application to other surface shapes.

The technical problem addressed by the present invention is to provide a non-destructive testing device particularly for a UAV, as well as a UAV and a kit comprising the non-destructive testing device, that are structurally and functionally configured

to at least partially overcome one or more of the disadvantages set out with reference to the prior art cited above.

Within this problem, a first objective of the invention is to provide an NDT device capable of improving the reliability of tests conducted by it with respect to known NDT devices.

A second objective of the present invention is to provide an NDT device allowing to significantly reduce the quantity of couplant needed to effectively ensure the transmission of measurements signal between the NDT sensor and the surface of the structure to be tested.

A further objective of the present invention is to provide a lighter NDT device that allows to increase the flying autonomy of a UAV equipped with it while ensuring an equivalent number of tests that the NDT device can conduct compared to UAVs equipped with known NDT devices.

SUMMARY OF THE INVENTION

According to an aspect of the invention, this problem is solved, and these objectives are reached by providing a non-destructive testing ("NDT") device, particularly for a UAV. The NDT device may comprise

- a contact sensor having a sensor surface configured to contact a target to be tested and/or
- a couplant dispensing nozzle attached to the contact sensor and configured to deliver couplant onto the sensor surface.

The couplant dispensing nozzle can be provided with a couplant dispensing section which can be arranged in a first region that can be annular to the sensor surface.

The couplant dispensing nozzle can have a ridge, in particular a projecting ridge, that surrounds a testing area where the sensor surface and the dispensing section are located.

As used herein, the term "ridge" may refer to a lip or an edge, more particularly a projecting lip or edge.

The ridge can be configured to conform or adhere to the target or create a fit, in particular a tight fit, to the target during testing so as to contain or at least partially contain between the testing area and the target the couplant dispensed through the dispensing section.

As used herein, the term "configured to adhere to the target" preferably refers to the ability to conform to the target when abutting the same, without however necessarily implying an ability to stick to the target.

The ridge can protrude relative to the sensor surface for adhering or creating a tight fit to the target when the sensor surface is pressed toward or against the target to test it.

Preferably, the ridge protrudes relative to the sensor surface leaving a gap between the sensor surface and the target when the sensor surface is pressed toward or against the target to test it.

According to this aspect, the couplant dispensed through the dispensing section into the testing area is advantageously contained between the testing area and the target by the ridge thus contrasting the dispersion of couplant. In this manner, the gap between the sensor surface and the target can be effectively filled.

As used herein, the term "testing area" refers preferably to the area between the sensor surface, the ridge, and the target being tested. The testing area includes preferably a first region that can be annular to the sensor surface and can be surrounded by the ridge. The testing area can also include the gap between the sensor surface and the target being tested.

As used herein, the term "contact sensor" refers preferably to a sensor for performing non-destructive testing of structures, in particular by making direct contact or indirect contact (e.g. through the presence of couplant) between the sensor itself and the structure being tested. For example, the contact sensor may be adapted for measuring a thickness or sensing a flaw of the structure to be tested.

The contact sensor may be configured to emit measurement signals and receive return signals in response thereto. The emitted measurement signals may be affected by the material of the structure being tested to provide return signals which are representative of the physical conditions of the structure.

It can be appreciated that an NDT device according to the present solution allows to effectively provide for consistent contact between the sensor surface and the target eventually improving reliability and effectiveness of the NDT device relative to the known NDT devices.

The couplant dispensing nozzle can comprise a couplant discharging section configured to allow excess couplant and/or air to flow out from the testing area.

The discharging section can be opposite to the dispensing section relative to the sensor surface, preferably so that, in operation, couplant dispensed into the testing area covers and particularly fully covers the sensor surface while flowing from the dispensing section toward the discharging section.

It will be appreciated that the drag encountered by the couplant flowing through the

testing area from the dispensing section toward the discharging area will increase the couplant pressure in the testing area, thereby forcing the couplant to fill the gap and contrast the presence of air bubbles between the sensor surface and the target.

The pressure of the couplant emerging from the dispensing section can be set to be of sufficient value to overcome the force with which the sensor surface is pressed toward or against the target so that the couplant can provide a couplant bearing, on which the contact sensor can ride, between the sensor surface and the target.

The discharging section can be opposite to the dispensing section relative to the sensor surface, preferably so that, in operation, couplant dispensed into the testing area flows out after covering the sensor surface and even more preferably so that, in operation, couplant dispensed into the testing area flows out only after fully covering the sensor surface.

According to an aspect of the present solution, the dispensing section can comprise one outlet, and preferably consists of a single outlet, located next to the sensor surface.

The ridge can extend around the sensor surface in order to form a limit for couplant flowing from the outlet.

The discharging section can comprise a discontinuity of the ridge to discharge an excess of couplant that can be dispensed into the volume delimited by the testing area, the ridge and the target in operation.

Through this discontinuity, excess couplant can be discharged after having filled the gap between the sensor surface and the target.

The term "discontinuity" refers preferably to a break or interruption in the otherwise continuous ridge that surrounds the sensor surface.

This break in the ridge allows for the discharge of excess couplant from the discharging section.

Essentially, it provides a specific point or opening in the ridge through which couplant can flow out, serving the functional purpose of discharging couplant that is in excess relative to that needed to fill the testing area when the sensor surface is placed on the target to be tested.

According to a particular aspect of the present solution, the ridge can extend circularly from near or next to the dispensing section to the discharging section.

In other words, the ridge can follow a circular shape in plant view.

The discontinuity can be diametrically opposite to the dispensing section, preferably so that, in operation, couplant dispensed into the testing area may advantageously

cover the sensor surface while flowing from the dispensing section toward the discharging section.

The discontinuity can be diametrically opposite to the dispensing section, preferably so that the couplant covers the sensor surface while flowing out of the testing area.

The discontinuity can be diametrically opposite to the dispensing section, preferably so that the couplant flows out of the testing area after having covered the sensor surface and even more preferably so that the couplant flows out of the testing area only after having fully covered the sensor surface.

The ridge is preferably made of a compliant or non-rigid material. The ridge may be made of a flexible and/or resilient material which may be configured to create a tight fit to the target, in particular when the ridge and/or the sensor surface are pressed against the target. The material of the ridge is preferably a polymeric material and even more preferably an elastomeric material. The ridge may thus ensure a tight fit to a surface of the target against which the sensor surface is pressed for testing.

Preferably, an elastomeric material having a Shore A hardness of 70-90 is used for forming the ridge to ensure a tight fit of the ridge to the target and to limit the pressure needed to achieve it.

In the context of the present disclosure, the configuration to "conform to the target", "adhere to the target", "create a fit to the target" or "create a tight fit to the target" preferably refers to the ability to produce a condition of contact between the ridge and the target that prevents or contrasts undesired leakage of couplant to the outside of the testing area in the zone of contact between the ridge and the target. It is understood, however, that such a condition does not exclude that excess couplant and/or air can intentionally be discharged through a discontinuity of the ridge such as through the couplant discharging section.

The contact sensor can be a contact ultrasonic sensor and preferably can be a dual crystal ultrasonic sensor; however, a single crystal ultrasonic sensor can be used without exceeding the scope of the appended claims.

The sensor surface is preferably planar; however, a curved sensor surface can be used without departing from the scope of the present invention.

According to another aspect of the present solution, the contact sensor can comprise or consist of an ultrasound scanner.

As used herein, the term "contact ultrasonic sensor" refers preferably to a sensor configured to perform ultrasonic testing ("UT") by making direct contact or indirect contact (e.g. through the presence of couplant) between the sensor and the structure

being tested.

As used herein, the term "couplant" preferably refers to a fluid medium that facilitates sound transmission between the NDT sensor and the surface of the structure being tested.

Advantageously, the couplant tends to flow in the testing area from the dispensing section toward the discharging section. It will be appreciated that such a flow can provide a cleaning action on the surface of the target which delimits the testing zone. In other words, the couplant emerging from the dispensing section also serves to clean the surface of the target which improves coupling and thus test reliability.

To further improve test reliability, the couplant can also include one or more cleaning agents such as a detergent, degreaser, abrasive, and/or acid for cleaning the target in the testing area.

Preferably, the NDT device is configured to adapt the viscosity of the couplant being dispensed depending on the operating temperature to improve test reliability. For this purpose, the NDT device may be operatively connected to a temperature sensor.

According to yet another aspect of the present solution, the NDT device comprises a releasable attachment element configured to releasably attach to the target. In particular, the releasable attachment element may be configured to releasably attach the contact sensor with the sensor surface and the couplant dispensing nozzle to the target, preferably so as to press the sensor surface and/or the ridge against the target. The releasable attachment element may be connected to the contact sensor and/or the couplant dispensing nozzle. The releasable attachment element includes, for example, a suction cup and/or one or more magnets which may be arranged flush with or slightly below the level of the sensor surface. It will be appreciated that the releasable attachment between the NDT device and the target allows for more stable contact between the sensor surface and the target, thereby improving test reliability.

An engagement surface configured to engage with the target may be defined on the attachment element and, for example, arranged flush with the surface of the one or more magnets. The ridge and/or the sensor surface may protrude slightly in front of the engagement surface. Preferably, the ridge protrudes slightly in front of the sensor surface, which in turn protrudes slightly in front of the engagement surface and/or in front of the surface of the one or more magnets.

It will be appreciated that the force exerted by the attachment element on the target allows for pressing the ridge against the target, thereby providing a tighter fit between the ridge and the target. The force exerted by the attachment element on

the target may also allow for pressing the sensor surface against the target, thereby improving the contact between the sensor surface and the target.

According to another aspect of the present solution, the NDT device is mounted on an arm and preferably at one longitudinal end of the arm. At the opposite longitudinal end, the arm may comprise a fastening element for releasably connecting to a UAV. The contact sensor and/or the arm may extend longitudinally along an axis. The sensor surface and/or the engagement surface may be perpendicular to the axis. The ridge may protrude in front of the sensor surface and/or the engagement surface in a direction parallel to the axis. The sensor surface may also protrude in front of the engagement surface in the same direction.

According to an even further aspect of the present solution an unmanned aerial vehicle ("UAV") is disclosed.

The UAV may comprise the above-described NDT device and a propulsion system, such as a flight propulsion system.

The propulsion system comprises for instance a frame which may support one or more rotors.

Preferably, the propulsion system comprises an outer protective cage.

The outer protective cage may define two separate spaces, one inside and the other outside the outer protective cage. The frame of the propulsion system may be mounted inside the outer protective cage. Additionally, the outer protective cage may be fixed to the frame of the propulsion system, preferably in a rigid manner.

Advantageously, the outer protective cage surrounds and protects the frame and/or the rotors of the propulsion system from impacts with external objects, including for example impacts with the surface of a structure to be non-destructively tested by the UAV. To better absorb impact energy, the outer protective cage may comprise a plurality of beams connected to each other to form a grid of polygons or a geodesic structure. Moreover, the outer protective cage may have an at least partially rounded outer shape, for example an at least partially ellipsoidal, ovoid, spheroidal or spherical outer shape, such that the frame and/or the rotors of the propulsion system are protected from all sides in case of a collision with an external object. It is understood that the outer shape of the outer protective cage may be substantially flat at the bottom of the UAV to advantageously facilitate stable landing. In addition, the UAV may comprise an image capture device and thus the outer shape of the outer protective cage may be substantially flat in a region where the image capture device may project through the outer protective cage so that the view of the image capture

device is advantageously unhindered over a wide angle of the environment around the UAV.

The UAV may also comprise an arm extending away from the propulsion system. Preferably, the contact sensor and the couplant dispensing nozzle of the NDT device are mounted on the arm.

The arm may be connected to the outer protective cage and extend to the outside of the same.

The arm may have a first end attached to the propulsion system, more particularly to the outer protective cage. The contact sensor and the couplant dispensing nozzle may be mounted at a second end of the arm that extends away from the propulsion system and preferably outward from the outer protective cage.

Preferably, the arm has a longitudinal development along, for instance, a linear or a curved path. The first and second ends of the arm may be opposite each other along the longitudinal development of the arm.

Preferably, the first end of the arm is attached or attachable to the outer protective cage. The arm may extend outward from the outer protective cage and, preferably, the second end of the arm is arranged at a distal end of the arm outside the outer protective cage, in such a manner that the second end of the arm is advantageously exposed to contact with the surface of the structure to be tested while the outer protective cage can advantageously be kept at a distance from the structure surface.

The arm may comprise a flexible section. The flexible section may be arranged along the longitudinal development of the arm, in particular between the first end and the second end. The flexible section may comprise a spring, such as a coil spring, or a resilient material, such as an elastomer. Advantageously, the degrees of freedom freed up by the flexible section improve the reliability of the contact between the NDT device and the target, whilst also facilitating stability of the propulsion system in hovering flight during testing of the target.

Preferably, the NDT device comprises the above-described releasable attachment element mounted on the arm, in particular on the second end of the arm. In this manner, the NDT device can stay attached to the target while the propulsion system is in hovering flight.

According to this aspect of the present solution, thanks to the enhanced efficiency in the use of the couplant of the NDT device, and to the consequent reduced need for couplant necessary to effectively carry out any single test, the UAV has extended flight autonomy relative to known UAVs that are able to perform the same number

of tests.

According to another aspect of the present solution, the UAV can conduct an increased number of tests on target structures relative to known UAVs having the same overall weight and flight performance.

As used herein, the term "structure" or "target structure" or "target" is to be understood in a broad sense not only with reference to buildings but also other types of structures, such as aircraft structures, cargo holds, fuel tanks, sewers, electrical power grids, just to name a few.

According to a further aspect of the present solution, a kit for non-destructive testing comprising the above-described NDT device is disclosed.

The dispensing nozzle can comprise a body and a plurality of front plates interchangeably attachable to the body to adapt to different contact sensors.

Each front plate can have a through hole through which, following the assembly of the body with the contact sensor and the front plate, the sensor surface is exposed for contacting a target to be tested.

Each front plate of said plurality has a different dimension to match a contact sensor with a correspondingly different dimension of the sensor surface.

In such a way it is possible to easily adapt the NDT device, or an UAV that is equipped therewith, with contact sensors having larger or smaller sensor surfaces by simply correspondingly equipping the body of the dispensing body with the appropriate front plate.

According to this aspect of the present solution, the ridge can protrude from the front plate and each front plate can have the ridge adapted to encircle the through hole, matching its dimension.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and advantages of the invention will be made clear by the following detailed description of a preferred, but not exclusive, exemplary embodiment thereof, illustrated by way of non-limiting example with reference to the appended drawings in which:

- Figure 1 is a schematic representation of the UAV comprising the NDT device according to an embodiment the invention;
- Figure 2 is a side view of the UAV comprising the NDT device according to an embodiment the invention;
- Figure 3 is a perspective view of an assembly comprising an arm and the NDT device according to an embodiment of the invention;

- Figure 4 is a front view of the NDT device of Fig. 3;
- Figure 5 is a sectional view of the assembly of Fig. 3;
- Figure 6 shows a detail of the sectional view of Fig. 5;
- Figure 7 is a perspective view of a kit comprising the NDT device of Fig. 3;
- Figure 8 is a perspective view of a detail of the UAV of Fig. 2.

PREFERRED EMBODIMENT OF THE INVENTION

Referring to the examples of Figs. 1-2, a UAV 1 for performing non-destructive testing ("NDT") of a target T according to embodiments of the invention comprises a propulsion system 2.

The propulsion system 2 may comprise a frame 20 which preferably supports one or more rotors 21. The rotors may be controlled by a control system and may be powered by one or more batteries, which may be mounted on the frame 20. The rotors may comprise one or more propellers which are preferably driven by electric motors. Within the scope of the invention, the propellers may however be driven by other types of motors, for instance combustion motors and the energy source provided in the form for instance of liquid fuel. In preferred embodiments, the propulsion system 2 may comprise three or four rotors 21, for instance in a rectangular configuration, the propellers being individually controlled, or controlled in pairs, to adjust the roll, yaw, and pitch angles of the UAV for flight and hovering of the UAV.

As shown in the embodiment of Fig. 2, the propulsion system 2 may comprise an outer protective cage 11. The outer protective cage preferably defines two separate spaces, one inside and the other outside the outer protective cage. The frame 20 of the propulsion system is preferably mounted inside the outer protective cage. The outer protective cage may be fixed to the frame of the propulsion system, preferably in a rigid manner.

Advantageously, the outer protective cage 11 surrounds and protects the frame 20 and/or the rotors 21 from impacts with external objects. To better absorb impact energy, the outer protective cage may comprise a plurality of beams 22 connected to each other to form a grid of polygons or a geodesic structure. Moreover, the outer protective cage may have an at least partially rounded outer shape, for example an at least partially ellipsoidal, ovoid, spheroidal or spherical outer shape, such that the frame and/or the rotors are protected from all sides in case of a collision with an external object. In embodiments, the outer protective cage may be substantially flat at the bottom to facilitate a stable landing.

The beams 22 may be connected together to form cage modules 23. The cage modules may have an outer pentagon shape and may be reversibly fixed together, in particular at the corners of their outer pentagon shape, for example by connectors 24. The connectors 24 may be permanently attached to the longitudinal extremities of the beams, or in a preferred embodiment, the connectors may be configured to allow removable connection between cage modules 23 such that the outer protective cage can be assembled from cage modules and disassembled at least partially. The assembly and disassembly of the cage modules facilitate shipping the UAV by providing the outer protective cage in parts that may be connected together prior to use, and disconnected in two or more parts for packaging, storage, and transport. The disassembly of cage modules 23 may also facilitate maintenance, for example by replacing cage modules with broken beams, or access to the frame 20 inside the outer protective cage.

The UAV may comprise a sensor system 17 coupled to the propulsion system 2. The sensor system 17 may comprise an image capture device, such as a video camera for capturing moving or still images, and may further comprise a lighting system, in particular for projecting infrared or visible light for the image capture device.

In embodiments, the sensor system 17 is coupled to the frame 20. If the outer protective cage 11 is present, it is preferred that the outer protective cage has an opening allowing the sensor system 17 to project therethrough so that the sensor system has an unhindered view over a wide angle of the environment around the UAV. Furthermore, the outer protective cage may be substantially flat in a region where the sensor system 17 projects through the outer protective cage 11 so that the view of the sensor system is broader.

Alternatively, or additionally, the sensor system 17 may be coupled to the outer protective cage 11 and may extend to the outside of the same. In embodiments, a sensor support system 18 is fixed on the outer protective cage 11 and the sensor system 17 may be coupled to the sensor support system 18.

It is preferred that the UAV comprises an arm 3. The arm 3 may be connected to the propulsion system 2, more particularly to the frame 20 or to the outer protective cage 11. Further preferred is that the arm 3 extends away from the propulsion system 2, more particularly away from the frame 20 and, if present, the outer protective cage 11. In embodiments, the outer protective cage 11 may have an opening allowing the arm 3 to project therethrough to the outside of the outer protective cage. However, it is preferred that the arm is arranged outside (in particular, completely

outside) the outer protective cage.

In embodiments, the arm 3 extends longitudinally, in particular along an axis X, from a first end 31 of the arm, which may be connected to the propulsion system, to a second end 32 of the arm, which is preferably opposite the propulsion system. The position of the arm 3 may be defined by the orientation of the axis X. The longitudinal development of the arm along the axis X can be substantially rectilinear, at least in a predefined operating position, and/or it can be adjustable through, for example, one or more adjustable joints 33. In other words, the arm may be articulated along its longitudinal development through one or more adjustable joints 33. The adjustable joints 33 advantageously allow a user to adjust the orientation or arrangement of the arm relative to the propulsion system to best suit the orientation of the surface of the target T or to bypass any obstacles between the UAV and the target, thereby facilitating attachment in hard-to-reach locations. Preferably, an adjustable joint 33 is provided at the first end 31 of the arm. As used herein, the term "adjustable joint" may refer to a hinge joint or an articulated joint, having preferably an adjustable angular position.

The arm may comprise a flexible section 30 that may be arranged along the longitudinal development X of the arm, in particular between the first end 31 and the second end 32. The flexible section 30, which is preferably a resilient flexible section, may be configured to exert an elastic bias urging the arm 3 toward a predefined operating position whilst advantageously allowing the propulsion system 2 to move relative to the second end 32 of the arm against the elastic bias. The flexible section 30 may comprise a spring 34, such as a coil spring, and preferably a sleeve 35 that surrounds the spring to protect it from dust, as shown in the example of Fig. 5.

Preferably, the second end 32 of the arm is arranged at a distal end of the arm outside the outer protective cage 11, in such a manner that the second end 32 of the arm is advantageously exposed to contact with the target while the outer protective cage 11 can advantageously be kept at a distance from the target.

The target may be, for example, the metal wall of a structure to be tested with ultrasound.

Referring to the examples of Figs. 3-7, an NDT device 100 according to embodiments of the invention is disclosed. The NDT device 100 can be mounted on the arm 3 and preferably on the second end 32 of the arm.

The NDT device 100 may comprise a contact sensor 101 and a couplant dispensing nozzle 103.

The contact sensor 101 and the couplant dispensing nozzle 103 can be mounted on the arm 3 and preferably on the second end 32 of the arm.

The contact sensor 101 may have a sensor surface 102 configured to contact a target T to be tested. The contact sensor can be a contact ultrasonic sensor, in particular a dual crystal ultrasonic sensor or a single crystal ultrasonic sensor. In embodiments, the contact sensor can be a 5 MHz ultrasonic sensor. The contact sensor can extend longitudinally along an axis that preferably coincides with the axis X of the arm. The sensor surface may be planar and preferably perpendicular to the axis of the contact sensor.

The couplant dispensing nozzle 103 may be attached to the contact sensor 101 and configured to deliver couplant onto the sensor surface 102.

Referring to the examples in Figs. 2 and 8, the UAV or the NDT device may comprise a couplant dispensing system 82. The couplant dispensing system 82 can be mounted on the propulsion system and preferably inside the outer protective cage 11. The UAV or the NDT device may include a tubing system 83 for fluidly connecting the couplant dispensing system 82 to the couplant dispensing nozzle 103. The tubing system may be flexible to allow for movement of the arm 3. The couplant dispensing system 82 may include a couplant reservoir 84 and a pump 85 fluidly connected thereto for delivering the couplant from the couplant reservoir 84 to the couplant dispensing nozzle 103.

In embodiments, the couplant dispensing system 82 is configured to adapt the viscosity of the couplant being dispensed depending on the operating temperature to improve test reliability. To this purpose, the couplant dispensing system 82 may also include a temperature sensor.

The couplant dispensing nozzle 103 can be provided with a couplant dispensing section 104 which can be arranged in a first region R that can be annular to the sensor surface 102.

The couplant dispensing nozzle 103 can have a ridge 105, in particular a resilient ridge, that surrounds a testing area A where the sensor surface and the dispensing section are located. In embodiments, the ridge 105 defines a crown, such as an annular crown, around the sensor surface 102.

The ridge 105 can be configured to create a fit, in particular a tight fit, to the target during testing so as to contain between the testing area A and the target T the couplant dispensed through the dispensing section 104.

The ridge 105 can protrude relative to the sensor surface 102 for fitting to the target

when the sensor surface is pressed toward or against the target to test it.

In this manner, the couplant dispensed through the dispensing section 104 into the testing area A is advantageously contained between the testing area and the target by the ridge thus contrasting the undesired dispersion of couplant. In this manner, the gap between the sensor surface and the target can be effectively filled.

The couplant dispensing nozzle 103 can comprise a couplant discharging section 107 configured to allow excess couplant to flow out from the testing area A.

The discharging section 107 can be opposite to the dispensing section 104 relative to the sensor surface 102. In this manner, during operation, couplant dispensed into the testing area A may advantageously cover the sensor surface 102 while flowing from the dispensing section 104 toward the discharging section 107.

The dispensing section 104 can comprise one outlet, and preferably consists of a single outlet, located next to the sensor surface 102, particularly in the testing area A.

In embodiments, the ridge 105 extends around the sensor surface 102 in order to form a limit for couplant flowing from the outlet.

The discharging section 107 can comprise a discontinuity of the ridge to discharge an excess of couplant that can be dispensed into the volume delimited by the testing area, the ridge and the target in operation.

Through this discontinuity, excess couplant can be discharged after having filled the gap between the sensor surface and the target.

The term "discontinuity" refers preferably to a break or interruption in the otherwise continuous ridge 105 that surrounds the sensor surface.

This break in the ridge 105 allows for the discharge of excess couplant from the discharging section. Essentially, it provides a specific point or opening in the ridge through which couplant can flow out, serving the functional purpose of discharging couplant that is in excess relative to that needed to fill the testing area when the sensor surface is placed on the target to be tested.

The ridge 105 can extend circularly from near or next to the dispensing section 104 to the discharging section 107. In embodiments, the ridge follows a circular shape in plant view, as shown in the example of Fig. 4.

The discontinuity can be diametrically opposite to the dispensing section 104 so that the couplant fully covers the sensor surface 102 while flowing out of the testing area A.

The ridge 105 is preferably made of a flexible and/or resilient material which may be

configured to create a tight fit to the target T. This material is preferably a polymeric material and even more preferably an elastomeric material. The ridge may thus ensure a tight fit to a surface of the target against which the sensor surface is pressed for testing.

In embodiments, an elastomeric material having a Shore A hardness of 75-85 is used for forming the ridge to ensure a tight fit of the ridge to the target and to limit the pressure needed to achieve it.

In embodiments, the dispensing nozzle 103 can comprise a body 110 that can be connected to the arm 3, in particular to the second end 32 of the arm.

The dispensing nozzle 103 can include a front plate 111 that can be made from a flexible and/or resilient material, in particular a polymeric material or an elastomeric material. In embodiments, the front plate 111 and the ridge 105 are made of the same material, preferably as one piece. The front plate 111 is preferably attachable to the body 110, in particular through a sealed connection.

The front plate 111 can have a through hole 112 through which, following the assembly of the body 110 with the contact sensor 101 and the front plate, the sensor surface 102 is exposed for contacting the target to be tested. Preferably the through hole 112 is encircled at least partially by the ridge.

The ridge 105 can protrude from the front plate 111, in particular in the direction of the axis X of the contact sensor. In embodiments, the ridge protrudes from the front plate up to or slightly beyond the level of the sensor surface 102. In other words, the foremost surface of the ridge can be flush with the sensor surface or can project slightly beyond the sensor surface, as shown for example in Fig. 6.

In embodiments, the body 110 comprises a tubular element 113 that can be configured to house the contact sensor 101 from a side opposite the sensor surface 102. The tubular element 113 can develop longitudinally along the axis X of the contact sensor.

The body 110 can include a flange 114 attachable to the tubular element 113, in particular through a releasable connection such as a threaded connection or a bayonet connection.

The couplant may enter the couplant dispensing nozzle 103 through an opening 115 defined in the body. The opening 115 may be fluidly connected to the couplant dispensing system 82 through the tubing system 83. A couplant distribution duct 116 may be defined in the space between the contact sensor 101, the body 110, and the front plate 111. The couplant may be delivered from the couplant distribution duct

116 to the testing area A through the couplant dispensing section 104.

In embodiments, the front plate 111 comprises an annular lip 117 that encircles the through hole 112. The annular lip can be configured to provide a sealed connection between the front plate and the contact sensor. The annular lip can comprise a discontinuity that defines the couplant dispensing section 104. In other words, the couplant can be delivered to the testing area through a discontinuity of the annular lip 117. The term "discontinuity" refers preferably to a break or interruption in the otherwise continuous annular lip 117 that surrounds the contact sensor. This break in the annular lip allows for the dispensing of couplant from the couplant distribution duct 116.

Preferably, the testing area A is defined between the sensor surface 102, the ridge 105, the annular lip 117, and the target being tested.

In embodiments, the NDT device 100 comprises a releasable attachment element 120 configured to releasably attach to the target. The attachment element 120 may have an engagement surface S configured to engage with the target. In embodiments, the attachment element 120 comprises one or more magnets 121, such as permanent magnets (particularly neodymium magnets) or electromagnets, which are preferably arranged flush with the engagement surface S. Additionally, or alternatively, the attachment element 120 may comprise a suction cup configured to use the negative fluid pressure of air to adhere to the surface of the target, creating a partial vacuum.

In embodiments, the ridge 105 protrudes from the front plate 111 up to or slightly beyond the level of the engagement surface S. In other words, the foremost surface of the ridge can be flush with the engagement surface S or can project slightly beyond the engagement surface. In embodiments, the engagement surface S is flush with the sensor surface 102.

In embodiments, the releasable attachment element 120 may be mounted on the flange 114. For example, a plurality of magnets 121 may be secured to the flange 114 for releasably attaching the flange to the target T, especially in the preferred case of a metallic target.

To ensure good contact for an NDT measurement to be made, the magnets 121 are preferably arranged flush with the sensor surface 102 and/or with the engagement surface S. In embodiments, the magnets are three in number so as to advantageously allow for an isostatic contact with the target.

The NDT device 100 and more particularly the flange 114 may comprise a number of

radial branches 122 on which the magnets may be mounted. The branches may lie on a plane perpendicular to the axis X of the contact sensor and may project radially around the same. It is preferable that the branches are spaced from each other by a constant angle A1. Referring to the example of Fig. 4, the flange has three branches that are preferably spaced from each other by a constant angle A1 of 120 degrees.

Referring to the example of Fig. 5, the NDT device optionally includes a laser 118 configured to aim at the target.

The NDT device may be operatively connected to the control system of the UAV via wiring 119.

Referring to the example of Fig. 7, a kit 10 for non-destructive testing comprising the NDT device 100 is disclosed wherein the dispensing nozzle 103 comprises the body 110 and a plurality of front plates 111 interchangeably attachable to the body to adapt to different contact sensors 101. The different contact sensors can also be part of the kit 10.

Each front plate 111 can have a through hole 112 through which, following the assembly of the body with the contact sensor and the front plate, the sensor surface is exposed for contacting the target to be tested.

Each front plate 111 of said plurality may have a different dimension to match a contact sensor 101 with a correspondingly different dimension of the sensor surface. In such a way it is possible to easily adapt the NDT device, or a UAV that is equipped therewith, with contact sensors having larger or smaller sensor surfaces by simply correspondingly equipping the body of the dispensing body with the appropriate front plate. The ridge 105 can protrude from the front plate 111 and each front plate can have the ridge adapted to encircle the through hole 112, matching its dimension.

The invention thus solves the proposed problem, achieving numerous advantages, including providing a reliable NDT device and a versatile UAV capable of safely and efficiently performing precise non-destructive testing of structures in hard-to-reach locations.

CLAIMS

1. Non-destructive testing, i.e. NDT, device (100), particularly for an unmanned aerial vehicle, i.e. UAV, the NDT device comprising
- a contact sensor (101) having a sensor surface (102) configured to contact a target to be tested and
- a couplant dispensing nozzle (103) attached to the contact sensor and configured to deliver couplant onto the sensor surface;
wherein the couplant dispensing nozzle is provided with a couplant dispensing section (104) and a ridge (105);
wherein the ridge at least partially surrounds a testing area (A) where the sensor surface and the dispensing section are located; the ridge (105) being configured to create a tight fit to the target during testing so as to at least partially contain between the testing area and the target the couplant dispensed through the dispensing section (104).

2. The NDT device (100) according to claim 1 wherein the couplant dispensing nozzle (103) comprises a couplant discharging section (107) configured to allow excess couplant to flow out from the testing area (A).

3. The NDT device (100) according to claim 2 wherein the discharging section (107) is opposite to the dispensing section (104) relative to the sensor surface (102), preferably so that, in operation, couplant dispensed into the testing area (A) covers the sensor surface while flowing from the dispensing section toward the discharging section.

4. The NDT device (100) according to claim 2 or 3 wherein the dispensing section (104) comprises one outlet (108) located next to the sensor surface; the ridge (105) extending around the sensor surface; wherein the discharging section (107) comprises a discontinuity (109) of the ridge through which excess couplant can be discharged.

5. The NDT device (100) according to claim 2, 3 or 4 wherein the ridge (105) extends circularly from next to the dispensing section (104) to the discharging section (107) which is diametrically opposite to the dispensing section.

6. The NDT device (100) according to one or more of the preceding claims wherein the ridge (105) protrudes relative to the sensor surface (102) for creating a tight fit to the target when the sensor surface is pressed against the target.

7. The NDT device (100) according to one or more of the preceding claims

wherein the ridge (105) is made of a flexible resilient material configured to create a tight fit to the target, in particular when the ridge is pressed against the target.

8. The NDT device (100) according to one or more of the preceding claims wherein the ridge (105) is made of a polymeric material and preferably an elastomeric material.

9. The NDT device (100) according to one or more of the preceding claims comprising a releasable attachment element (120) configured to releasably attach the contact sensor (101) with the sensor surface (102) and the couplant dispensing nozzle (103) to the target, preferably so as to press the sensor surface and/or the ridge against the target.

10. The NDT device (100) according to one or more of the preceding claims wherein the contact sensor (101) is a contact ultrasonic sensor or an ultrasound scanner.

11. The NDT device (100) according to one or more of the preceding claims further comprising the couplant, wherein the couplant includes one or more cleaning agents for cleaning the target in the testing area (A).

12. Unmanned aerial vehicle, i.e. UAV, (1) comprising
- a propulsion system (2),
- an arm (3) extending away from the propulsion system, and
- the NDT device (100) according to one or more of the preceding claims, wherein the contact sensor (101) and the couplant dispensing nozzle (103) are mounted on the arm.

13. The UAV (1) according to claim 12 wherein the propulsion system (2) comprises an outer protective cage (11), the arm (3) being connected to the outer protective cage and extending to the outside of the same.

14. Kit (10) for non-destructive testing comprising the NDT device (100) according to one or more of claims 1-11 wherein the dispensing nozzle (103) comprises a body (110) and a plurality of front plates (111) interchangeably attachable to the body to adapt to different contact sensors (101); each front plate has a through hole (112) through which, following the assembly of the body with the contact sensor and the front plate, the sensor surface (102) is exposed for contacting a target to be tested; wherein each front plate (111) of said plurality has a different dimension to match a contact sensor (101) with a correspondingly different dimension of the sensor surface.