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TITLE OF THE INVENTION

AN APPARATUS FOR ULTRASONIC INSPECTION OF FLAWED MATERIALS

BACKGROUND OF THE INVENTION

(a) Field of the Invention

The present invention relates to apparatus for ultrasonic inspection of flawed materials, and in particular, an apparatus, which employs water irrigated sensor head to inspect flawed material or crack formation on material, for instance, on the wings of an aircraft.

(b) Description of the Prior Art

As the structures of an aircraft are mounted/coupled together by a plurality of fastening means, for instance, the fasteners, nuts and bolts, and stress concentration occurs most often around the fastener holes, the potential of small cracks appearing is high on the stressed areas of the top and the bottom edges of the fastener holes. In the case of countersunk holes, cracks may also form in the neck area of the countersunk. The crack that could occur usually radiates outward perpendicularly or near perpendicularly to the circumference of the fastener holes. Overtime, the cracks will grow larger and ultimately affect the safety of the aircraft.

Based on current inspection standards of the aircraft under consideration, the cracks must be detected when it is no larger that approximately 1.25mm in length and 1.25mm in height.

The ultrasonic inspection makes use of very high frequency sound waves to penetrate the material to be inspected. The sound wave reflects when

it encounters an interface involving a change in material, which can be a crack or defect in the material. An ultrasonic probe usually houses a piezoelectric crystal to perform the dual functions of transmitting ultrasonic pulses and receiving the reflected pulses from defects. The time-fo-flight data of the refracted signal can be used to determine the defect location with reference to the probe, and the received signal amplitude can be used as an approximate assessment of the severity of the defect. One of the problems with ultrasonic inspection is that it cannot easily penetrate materials with high acoustic attenuation such as air. Therefore, perfect coupling involving no air bubbles between the ultrasonic probe and the material surface is desirable at all times during the inspection. The difficulty of providing good coupling while inspecting in the upward position should be highlighted.

The deeper the flaw below the material surface, the smaller the signal amplitude will be for a given flaw size. Therefore, both the probe and the instrument must be calibrated before each inspection in order to inspect a fastener hole for cracks; the accuracy of the inspection depends on the calibration set and to rotate the instrument concentrically around the fastener for complete coverage. Manipulation of an ultrasonic instrument to achieve this accuracy is difficult when performed manually.

US Patent No. 5,469,744 issued to Patton et al has proposed a Dripless Bubbler system in "Developments and Testing of The Dripless Bubbler Ultrasonic Scanner". The system discloses a novel approach to provide reliable coupling between the ultrasonic sensors and the wing surface in order to ensure good ultrasonic measurements.

US Patent No. 5,481,916 issued to Macecek et al discloses an apparatus which is used for non-destructive testing for flaws in materials, comprising a housing assembly for passage over the surface of the housing assembly; an ultrasonic probe for transmitting ultrasonic energy to the material to be tested; an eddy current probe for the generation of eddy currents in the material; and a rotating means for rotationally moving the eddy current probe about the ultrasonic probe. This conventional apparatus using eddy current is not reliable in detecting some forms of degradation and could not discriminate between combinations of different types of flaws that were found in the same position.

SUMMARY OF THE INVENTION

Accordingly the present invention has overcome these drawbacks and limitations by allowing a water irrigated sensor head as a testing device to provide an ultrasonic inspection and employing an automated device to operate the testing device.

Yet another object of the present invention is to provide an apparatus for ultrasonic inspection of flawed material, wherein the ultrasonic sensor is reliably coupled to the wing surface of an aircraft to be inspected in order to detect cracks around the fastener holes thereon.

Another object of the present invention is to provide an apparatus for ultrasonic inspection of flawed material, wherein an ideal flow-suction system is provided to the apparatus so as to adequately contain the coupling to prevent overflow.

It is another object of the present invention to provide an apparatus for ultrasonic inspection of flawed material, wherein a robot controller manipulates the apparatus and an X-Y table enabling automated ultrasonic inspection of high accuracy.

An aspect of the present invention is to provide an apparatus for ultrasonic inspection of flawed materials, comprising: a housing assembly having an inner chamber and an outer chamber; two compression wave transducers being angled to produce refracted ultrasonic shear wave beams; two coupling monitoring transducers being used to receive ultrasonic signals from the compression wave transducers; a sensor holder attached to the housing assembly at a plurality of points; two fluid inlets and a suction outlet positioned to provide a fluid filled inner chamber for accurate inspection in the upward and downward direction and a brush assembly including a plurality of annular brushes to ensure a fluid tight seal and to provide the appropriate fluid column height during the process of ultrasonic inspection.

A further aspect of the present invention is to provide an apparatus for ultrasonic inspection of flawed materials further comprises a means manipulated by a robot controller and an X-Y table which enables the accurate positioning of the sensors to perform complete flaw detection around the fastener hole by clockwise rotation and is linked to the central processor or computer to perform the ultrasonic inspection on a to-be-tested material automatically.

Additional advantages and novel features of the invention will be set forth in part in the description that follows, and in part will become apparent to

those skilled in the art. The advantages of the invention may be realized and attained by means of the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a top view of the apparatus (water irrigated sensor head) for ultrasonic inspection in accordance with the present invention.

Fig. 2 shows a sectional view of the apparatus (water irrigated sensor head) for ultrasonic inspection in accordance with the present invention.

Fig. 3 is a perspective view of an apparatus for ultrasonic inspection of the present invention, wherein the brush assembly has been removed from the water irrigated sensor head of the present invention.

Fig. 4 is a perspective exploded view of the apparatus (water irrigated sensor head) (WISH) brush assembly in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to Figs. 1 to 4, and in particular, to Fig. 1, which is a cross sectional view of the Water Irrigated Sensor Head (WISH) 100 for automated ultrasonic inspection of flaw in material, comprises a pair of compression wave transducers, 10, 20, a brush assembly 25, and a pair of coupling monitoring transducers 30, 40, all being housed in a sensor holder 50. In accordance with the present invention, the WISH 100 includes an

inner chamber 92 and an outer chamber 94, the two compression wave transducers 10 and 20 are appropriately angled so as to produce refracted ultrasonic shear wave beams which enable the detection of flaws around closely-spaced fasteners, and the sensor holder 50 is machined to provide a 35 and 70 degree angle for the compression wave transducers 10 and 20. The sensor holder 50 is attached to the Water Irrigated Sensor Head (WISH) housing 90 at a plurality of points. As shown in Fig. 2, a cross sectional view of WISH assembly, an O-ring 60 is provided between the sensor holder 50 and the WISH housing 90 to effect a fluid tight seal. A plurality of O-rings and sealant are used between the transducers 10, 20, 30, 40 and the sensor holder 50 for the same purpose (fluid tight seal). O-rings 70, 80 are mounted between the WISH housing 90 and the brush assembly 25 to ensure a fluid tight seal. The brush assembly 25 includes a plurality of annular brushes 150 designed to provide a 12 mm fluid column for good coupling and refraction of the ultrasonic signals and a WISH brush holder 160 having a plurality of threads at the circumferential edge thereof being screwed to the WISH housing 90.

In the present preferred embodiment, the coupling monitoring transducers 30, 40 are used only as receivers of ultrasonic signals to check for the presence of water in the inner chamber 92 of the WISH 100. The signals of both the angled shear wave transducers 10, 20, and the coupling monitoring transducers 30, 40 are processed by a central processor 210 being installed with an appropriate software for crack detection algorithm.

In accordance with the present invention, a water flow assembly (referring to Fig. 3) is connected to the WISH 100. In this case, the coupling medium for the ultrasonic inspection is water, and water is supplied by a

water tank 211 and is pumped to a pair of inlet points on the WISH housing 90 via a tube 212 and an elbow assembly 213. The fluid inlets; the tube 212, the elbow assembly 213 and the fluid outlet; elbow assembly 214 are spaced furthest (180°) apart to ensure that the transducers 10, 20, 30, 40 are completely submerged, and to provide continuous coupling between the transducers 10, 20, 30, 40 and a component under test when the WISH 100 is in the upward and downward position. A suction outlet 96 is positioned at the outer chamber 94 to provide a fluid filled inner chamber 92 for accurate inspection in the upward and downward direction.

In accordance with the present preferred embodiment, the fluid inlet and the suction outlet are appropriately placed so that both the inlet and the outlet are positioned furthest apart to allow the flow of fluid to fill the inner chamber 92 of the housing assembly and provides a good ultrasonic coupling for inspection in which the apparatus is positioned upward and downward.

The annular brushes 150 separate the WISH 100 into the inner chamber 92 and the outer chamber 94. The brush assembly 25 provides the ideal height of a 12 mm water column for complete immersion of the transducers 10, 20, 30, 40 and thus reliable coupling for ultrasonic inspection in accordance with the present invention is obtained.

The construction of the brush assembly 25 along with the water flow assembly provides coupling that fills the inner chamber 92 of the WISH 100 providing a convex water level. Water overflowing out of the inner chamber 92 will be subsequently sucked out from the outer chamber 94 thought the outlet point on the WISH housing 90 and drawn back into the water tank through the tube and elbow assembly 213. The suction from

the water tank is provided using a self-priming, submersible pump, which creates a vacuum chamber inside the water tank and provides the computer controlled water flow. In operation, a robot controller brings the WISH 100 in close proximity to the component under test before complete contact. In this way, the sustained convex water level provided by the present device and surface tension effect enables elimination of air gaps or bubbles between the component under test and the sensors and provides reliable coupling.

Referring to Fig. 4, there is shown a perspective exploded view of the WISH assembly, wherein the brush assembly has been removed. As shown in the figure, a cylindrical holder 217 is attached to the WISH housing 90 and covers the output of the transducer assembly (i.e., the transducers 10, 20, 30 & 40). The holder 217 is provided with outlets (not shown) for connection of signal wires from the transducer assembly to the central processor 210. A cylindrical tool holder 218 and a Teflon identification plate 219 form into a tool identification assembly, which is attached by the cylindrical holder 217. In accordance with the present invention, a robot controller 210 controlled by the central processor 210 manipulates the WISH assembly.

In accordance with the present invention, in order to inspect the cracks or flaws around a fastener hole of a to-be-tested component, an angled shear-wave is produced using an appropriately orientated transmit/receive immersion compression wave probe. The ultrasonic beam to material surface entry point is positioned at an offset distance from the center of the fastener hole. The probe system is rotated around the hole by a robot controller to detect cracks or flaws that may occur anywhere around the circumference of the fastener hole. The sound

wave penetrates the material tangential to the circumference of the hole. The position of the beam entry point from the fastener hole varies with the thickness of the wing skin as well as the size of the fastener.

While this invention has been described in terms of a specific preferred embodiment, it is contemplated that various alterations and modifications thereof will become apparent to those skilled in the art. It is therefore intended that the appended claims included all such alterations and modifications as fall within the true spirit and scope of the present invention.

CLAIMS

1. An apparatus for ultrasonic inspection of flawed materials, comprising:
   (a) a housing assembly having an inner chamber and an outer chamber;
   (b) two compression wave transducers being angled to produce refracted ultrasonic shear wave beams so as to inspect closely spaced fasteners accurately;
   (c) two transducers being used to receive reflected compression wave to monitor adequate ultrasonic coupling between said transducers of (b) and the part to be tested;
   (d) a sensor holder attached to the housing assembly at a plurality of points; and
   (e) a brush assembly including a plurality of annular brushes to ensure a fluid tight seal and provide a 12 mm water column level in the process of ultrasonic inspection.

2. The apparatus as set forth in claim 1, wherein further comprises a means to monitor and to process the ultrasonic signals received by the coupling monitoring transducers to detect flaws in the part to-be-tested.

3. The apparatus as set forth in claim 2, wherein the means includes a central processor or a computer.

4. The apparatus as set forth in claim 1, further comprises a water flow assembly to provide a coupling medium for the ultrasonic inspection.

5. The apparatus as set forth in claim 4, wherein the water flow assembly includes a water tank and a pump.

6. The apparatus as set forth in claim 5, further comprises a self-priming, submersible pump to supply pressurized fluid for ultrasonic inspection.

7. The apparatus as set forth in claim 1, wherein the brush assembly provides a coupling with a 12mm water column level to fill the inner chamber of said housing assembly.

8. The apparatus of claim 1, wherein the brush assembly consists of a fluid inlet and a suction outlet appropriately placed so that the inlet and the outlet are positioned furthest apart to allow the flow of fluid to fill said inner chamber of the housing assembly and provides a good ultrasonic coupling for inspection in which the apparatus is positioned upward or downward.

9. The apparatus as claimed in claim 1, wherein said inner chamber also consists of an inlet that provides suction to assist fluid in filling up the inner chamber when the apparatus is placed downward onto the part to be tested.

10. The apparatus as claimed in claim 1, wherein a tool changer is used to deploy the housing assembly.

11. The apparatus as claimed in claim 1, further comprises a means manipulated by a robot controller and an X-Y table accurately positions the sensors to enable complete coverage for flaw detection and is linked to the central processor or computer to perform the ultrasonic inspection on a to-be-tested material automatically.

12. An apparatus for ultrasonic inspection of flawed materials, comprising:

(a) a housing assembly having an inner chamber and an outer chamber;

(b) two compression wave transducers being angled to produce refracted ultrasonic shear wave beams so as to inspect closely spaced fasteners accurately;

(c) two transducers being used to receive reflected compression wave to monitor adequate ultrasonic coupling between said transducers of (b) and the part to be tested;

(d) a sensor holder attached to the housing assembly at a plurality of points;

(e) two fluid inlets and a suction outlet positioned to provide a fluid filled inner chamber for accurate inspection in the upward and downward direction; and

(f) a brush assembly including a plurality of annular brushes to ensure a fluid tight seal and provide a 12 mm water column level in the process of ultrasonic inspection.