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APPARATUS FOR INSPECTING AIRCRAFT BODY AND METHOD OF INSPECTING SAME

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an apparatus for inspecting an aircraft body and a method of inspecting the aircraft body particularly capable of efficiently and nondestructively inspecting a surface of the aircraft body during not only a stage of manufacturing the aircraft but also a stage after the aircraft is in a commercial flying operation.

Description of the Related Art

A conventional aircraft body had been mainly constituted by metal materials consisting of duralumin, aluminum alloy and composite material thereof. However, in recent years, from a viewpoint of economical efficiency of flight and environmental pollution control measure or the like, CFRP (carbon fiber reinforced plastics) material has been adopted for the purpose of further decreasing a total weight of the aircraft body. In general, strength properties of CFRP material per se are sufficient for the flight performance of the aircraft. However, after the aircraft entered into actual service, there are liable to occur various defects such as aged deterioration, deterioration caused by environmental condition, abnormality in adhesion between the adjacent CFRP layers caused by material fatigue during the flying

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operation or the like.

Therefore, it is very important at all times to analyze and evaluate whether such defects would occur or not, so that the aircraft is required to be subjected to a periodical inspection (refer to patent document: Japanese Patent Application Laid-Open (Unexamined) No. 7-76289).

However, in the prior arts, there is no suitable inspection method for inspecting large-sized structures such as aircraft or the like. Therefore, a visual inspection, examination by feeling with the hand, liquid penetration inspection, a manual-type ultrasonic inspection apparatus for manually scanning the defected portions or the like, have been mainly adopted and utilized as the inspection method.

However, these conventional inspection methods are all inefficient method, and provide problems such that an efficiency of the inspecting operation and inspection accuracy are low, because there are many cases where the inspection operation requires to trusting a skilled worker's intuition. According to these conventional inspection methods, it has been difficult to obtain objective inspection data capable of analyzing and evaluating a history of the aircraft body after entering into service of the aircraft, thus arising a problem such that high quality of the aircraft cannot be secured.

Further, as a conventional inspecting method, there has been partially adopted a nondestructive inspection method in which the aircraft body is inspected by utilizing X-ray. In the

above nondestructive inspection method using X-ray, however, it is necessary to provide a shielding structure for preventing the inspection worker from being exposed to radioactive ray. Therefore, there has been posed problems that the nondestructive inspection method is limited to a relatively small-sized jet-engined airplane, and the inspection can be limitedly performed to only a narrow area.

SUMMARY OF THE INVENTION

The present invention was conceived in consideration of the above circumstances encountered in the prior art and an object of the invention is to provide an apparatus for inspecting an aircraft body and a method of inspecting the aircraft body, which is capable of accurately and efficiently conducting a nondestructive inspection with respect to the aircraft body without relying on any visual inspection or touching-examination (manipulation test).

This and other objects can be achieved according to the present invention by providing, in one aspect, an apparatus for inspecting an aircraft body comprising:

an inspection vehicle traveling to every direction in a horizontal plane;

a laser device mounted on the inspection vehicle and configured to radiate a laser beam to an aircraft body to be inspected and to receive a reflected laser beam from the aircraft body;

an ultrasonic probe mounted on the inspection vehicle and

configured to emit an ultrasonic wave to the aircraft body and to receive a reflected ultrasonic wave from the aircraft body; and

a control device configured to control the traveling of the inspection vehicle in response to a signal transmitted from the laser device and to display ultrasonic inspection data of the aircraft body in response to a signal transmitted from the ultrasonic probe.

In a preferred embodiment of this aspect, the ultrasonic probe may be provided for a tip end portion of a multi-spindled robot arm.

The inspection vehicle may include a magnetic sensor which is responsive to a magnetic tape disposed on a ground.

The ultrasonic probe may include a contact type touch sensor in a vicinity of the ultrasonic probe, the touch sensor being configured to prevent an influence of curved surface of the aircraft body from mixing into the ultrasonic inspection data.

The ultrasonic probe may include a three-dimensional sensor in a vicinity of the ultrasonic probe, and the control device is configured to display, in combination, the ultrasonic inspection data together with positional data obtained from the three-dimensional sensor.

The control device is configured to analyze and evaluate a fatigue caused by a flight operation of the aircraft body by comparing the obtained ultrasonic inspection data with those obtained at proceeding time before the flight operation. The control device may be arranged to a position apart from the

aircraft body, and the control device is configured to wirelessly receive a signal transmitted from the ultrasonic probe.

It may be desired that a plurality of inspection vehicles are connected to each other by means of a horizontally transferring mechanism, and the ultrasonic probe and the laser device are mounted on the horizontally transferring mechanism.

Furthermore, in another aspect of the present invention, there is also provided a method of inspecting an aircraft body comprising the steps of:

preparing an inspection vehicle traveling to every direction in a horizontal plane and being mounted with a laser device and an ultrasonic probe;

radiating a laser beam to the aircraft body to be inspected, the laser beam being generated by the laser device mounted on the inspection vehicle;

determining a position of the inspection vehicle with respect to the aircraft body by utilizing the laser beam; and

performing an ultrasonic inspection to the aircraft body by the ultrasonic probe mounted on the inspection vehicle.

According to the present invention constructed as above, there can be provided an apparatus for inspecting an aircraft body and a method of inspecting the aircraft body, which is capable of accurately and efficiently conducting a nondestructive inspection with respect to the aircraft body without relying on any visual inspection or touching-examination (manipulation test).

The nature and further characteristic features will be made

clearer from the following descriptions made with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

FIG. 1 is a view showing a state of an inspecting apparatus for inspecting an aircraft body according to a first embodiment of the present invention, in which FIG. 1A is a plan view and FIG. 1B is a front view of the apparatus.

FIG. 2 is a view showing a laser system provided for the apparatus for inspecting the aircraft body according to the first embodiment of the present invention, in which FIG. 2A is a plan view and FIG. 2B is a side view of the laser system.

FIG. 3 is an elevation view showing a first example of an inspection vehicle provided for the apparatus for inspecting the aircraft body according to the first embodiment of the present invention.

FIG. 4 is an elevation view showing a second example of an inspection vehicle provided for the apparatus for inspecting the aircraft body according to the first embodiment of the present invention.

FIG. 5 is a front view showing a probe follow-up mechanism provided for the apparatus for inspecting the aircraft body according to the first embodiment of the present invention.

FIG. 6 is an explanatory view explaining a transmission of the inspection data transmitted through wireless communication

in the apparatus for inspecting the aircraft body according to the first embodiment of the present invention.

FIG. 7 is a view showing a first example of an apparatus for inspecting an aircraft body according to a second embodiment of the present invention, in which FIG. 7A is a plan view and FIG. 7B is a side view of the apparatus.

FIG. 8 is a plan view showing a second example of the apparatus for inspecting an aircraft body according to the second embodiment of the present invention.

FIG. 9 is a plan view showing a third example of the apparatus for inspecting an aircraft body according to the second embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The first and second preferred embodiments of the apparatus for inspecting an aircraft body according to the present invention will be explained hereunder with reference to the accompanying drawings.

[First Embodiment]

The apparatus for inspecting an aircraft body according to the present embodiment comprises: a laser system; a hexaxial (six-spindled) manipulator-type robot arm holding a linear arrayed ultrasonic probe; an elevating mechanism for vertically transferring the robot arm; a horizontally traveling mechanism for horizontally traveling the robot arm; and an inspection vehicle equipped with the elevating mechanism and the horizontally

traveling mechanism to be capable of freely access to the aircraft body by being transferred in any directions in a horizontal plane. A position of the inspection vehicle with respect to the aircraft body is determined by the action of the laser system.

Operations of the above robot arm, the elevating mechanism and the horizontally traveling mechanism are controlled by a control device through a wireless remote transmitting system. Ultrasonic waveform data obtained from the linear arrayed ultrasonic probe are transmitted to the control device through the wireless remote transmitting system. Then, the ultrasonic wave form data are calculated in the control device under a predetermined condition of scanning defects, thereby to output the calculation results. The calculation results are displayed as an image data, and analyzed and evaluated by cross-checking with another data measured at past time.

The inspection vehicle accesses to the aircraft body at a distance of about 1 m by the action of the laser system, and then a position of the inspection vehicle with respect to the aircraft body is determined by the action of the laser system thereby to set an original measuring point. After setting the original measuring point, the ultrasonic probe is set to follow-up the surface of the aircraft body on the basis of the three-dimensional data of the aircraft body.

A lower portion of the inspection vehicle is provided with a magnetic sensor. The magnetic sensor detects magnetism of a magnetic tape provided on a ground or embedded under the

ground, so that the inspection vehicle is moved and guided along the aircraft thereby to perform the inspection with respect to whole aircraft body. The linear arrayed ultrasonic prove adopts a following mechanism utilizing springs as shown in FIG. 5, and the ultrasonic probe is configured so that a deviation within a range of 10 mm of a contact point of the ultrasonic prove can be absorbed by a deformation of the springs.

After a relative position between the inspection vehicle and the aircraft body is determined, even if there is caused any manufacturing error or positioning error originated from a difference between CAD (Computer Aided Design) data of the aircraft body and an actual surface position of the aircraft body, a contact position error of a probe shoe can be absorbed by the action of the springs provided to a probe holder side of the following-up mechanism.

Further, even in a case where a shape of the curbed surface of the aircraft body is different from the aforementioned CAD data, or in a case where the curbed surface of the aircraft body is largely deformed and an amount of the deformation exceeds the range of the following-up operation of the following-up mechanism, a contact-type touch sensor provided in the vicinity of the probe detects shape-irregularity of the surface of the aircraft body and stops performing a wasteful inspection.

Hereunder, the first embodiment of the apparatus for inspecting an aircraft body according to the present invention will be described in more detail with reference to FIG. 1 to FIG. 6.

FIG. 1A and FIG. 1B are plan view and front elevation view respectively showing an entire configuration of the apparatus for inspecting the aircraft body according to the first embodiment of the present invention. As shown in FIG. 1A and FIG. 1B, with respect to the aircraft body 1 manufactured of mainly CFRP (carbon fiber reinforced plastic) material or composite material of CFRP, the position of the inspection vehicle 10 mounted with an ultrasonic inspection apparatus is determined by utilizing the laser system. In order to accurately determine the position of the inspection vehicle 10 with respect to the aircraft body 1, the inspection vehicle 10 adopts a structure comprising traveling wheels and free wheels each having a wheel shaft turnable at an angle of 90 degrees with respect to the wheel shaft of the traveling wheel, so that the inspection vehicle 10 can travel in any directions in a horizontal plane on a ground. Further, a laser beam acceptor 31 for receiving the laser beam 30 is provided for a lower portion of a hull body of the aircraft body 1.

FIG. 2A is a plan view showing the laser system, while FIG. 2B is a side view of the laser system. The laser system is configured so that a laser beam radiating device 32 provided on a level adjusting mechanism 33 radiates a laser beam 30. The radiated laser beam 30 is received by the laser beam receiver 31 and the radiated laser beam30 is reflected at the laser beam receiver 31. The reflected laser beam is again received by the laser device 32. The received laser beam as optical signal is converted into an electronic signal at an communication converter

34. The electronic signal is transmitted to a control device 35 through a communication cable 36.

FIG. 3 is an elevation view showing an inspection vehicle 10 mounted with the laser system and the ultrasonic system, and the inspection vehicle 10 is capable of traveling in any directions in a horizontal plane. That is, the inspection vehicle 10 comprises a bogie 11, and the bogie 11 is provided with: traveling wheels 41; a servo motor 44 for driving the traveling wheels 41; a jacking mechanism 43 for changing the traveling directions; universal wheels 42 for freely traveling the inspection vehicle 10 in any directions; and a servo motor 45 for driving the universal wheels 42. Further, an upper portion of the bogie 11 is provided with elevation guide 47 so as to extend vertically. An elevation bracket 46 is attached to the elevation guide 47 by means of an elevation shaft, not shown, and a servo motor 45. A horizontally traveling mechanism 20 is attached to the elevation bracket 46.

A level adjusting mechanism 33 for adjusting a level of the laser device 32 is attached to an upper portion of the horizontally traveling mechanism 20, while a LM (Linear Motor) guide block 21 is attached to a lower portion of the horizontally traveling mechanism 20. Further, a rail 22 is attached to an upper portion of the elevation bracket 46, thus enabling the bogie 11 to transfer in horizontal direction by the action of the servo motor, not shown, for horizontal transferring.

Furthermore, a root portion of a six-spindled robot 12 is attached to an upper portion of the elevation guide 47 so as to be

vertically movable, while an ultrasonic probe 13 is provided to a tip end portion of the six-spindled robot (arm) 12. A water supplying hose 14 is connected to the ultrasonic probe 13.

FIG. 4 shows a modification of the inspection vehicle 10. That is, there is provided a structure in which the level adjusting mechanism 33 of the laser device 32 and the six-spindled robot 12 are firmly supported from both sides by means of the elevation guides 47a and 47b. According to the above structure, stability of the inspection vehicle 10 can be greatly improved, and the inspection vehicle 10 can provide a sufficient resistance against overturning.

Using thus configured laser system provided on the inspection vehicle 10, the inspection vehicle 10 is transferred to the aircraft body 1 and a position of the inspection vehicle 10 against the aircraft body 1 is precisely determined. The laser beam receiver 31 is disposed on a line connecting a tip end portion and a rear portion of the aircraft body. Then, using the laser receiver 31 and the laser device 32, a degree of parallelization between the inspection vehicle 10 and the aircraft body 1 is measured and calculated, whereby the position of the inspection vehicle 10 is adjusted so that the inspection vehicle 10 and the aircraft body 1 become in parallel to each other.

A magnetic tape 48 is disposed on a line of which position on a floor (ground) is determined so as to be in parallel with the aircraft body 1. The magnetic tape 48 is disposed on the line by using the laser beam as a guide. The magnetic tape 48 is

detected by a magnetic sensor 49 provided to the inspection vehicle 10, so that the inspection vehicle 10 is transferred in parallel with the aircraft body 1.

FIG. 5 shows a following-up mechanism of the probe which is attached to a tip end portion of the six-spindled robot 12. That is, a probe holder spindle 24 is attached to a tip end portion of the robot hand 15. The following-up mechanism is configured to perform a following-up operation in a vertical direction by the action of the spring shaft 16 and the spring 17 through plates 27a and 27b. Further, the ultrasonic probe 13 is supported by a guide plate 25 and a pin 18. The ultrasonic probe 13 is configured to be turnable around the pin 18 as a fulcrum (supporting point), thus enabling the ultrasonic probe 13 to accurately follow-up the curved surface of the aircraft body 1. Furthermore, water 23 is supplied through a water supplying hose 14 to a gap between a probe shoe 26 and the surface of the aircraft body 1, so that ultrasonic wave 19 can be transmitted with a high efficiency.

FIG. 6 is an explanatory view explaining the transmission of the inspection data by utilizing a wireless communication system. The ultrasonic inspection data of the aircraft body 1 is transmitted with electric wave (radio wave) 38 by a wireless system 39 mounted on the inspection vehicle 10, and the carried inspection data is transmitted to a control device 35 through a data receiving unit 37 disposed apart from the aircraft body 1. In this connection, the transmission system may be also

configured to form a structure in which a three-dimensional sensor is provided in the vicinity of the ultrasonic probe 13, a positional data is obtained by the action of the three-dimensional sensor and the six-spindled robot, whereby the positional data together with the ultrasonic inspection data are wirelessly transmitted.

According to the present embodiment, due to the combination structure of the six-spindled robot 12 and the ultrasonic prove 13 mounted on the magnetic induction type inspection vehicle 10, the inspection vehicle 10 can freely travel on the ground around the aircraft body 1 as a huge structural product, so that an ultrasonic nondestructive inspection can be smoothly performed with a relatively simple setting-up operation. As shown in FIG. 3, when the laser system and the magnetic tape 48 are used as a method of determining the position of the inspection vehicle 10, the inspection vehicle 10 can be accurately accessed to the aircraft body 1. Further, when a plurality of ultrasonic sensors are provided to the inspection vehicle 10, it becomes possible to prevent the inspection vehicle 10 from being contact or collide with the aircraft body 1.

Further, when the data transmission unit 37 for wirelessly transmitting the ultrasonic inspection data to the control device 35 is provided, the control device 35 for analyzing and displaying the defects can be installed to a position apart from the aircraft body 1, so that an installation space for the control device 35 can be saved around the aircraft body 1.

Furthermore, due to the combination structure of the laser measuring system, CAD data of the aircraft body 1 and the following-up mechanism, the inspecting operation can be performed even if accuracy in position of the inspection vehicle 10 is low, thus improving the inspection efficiency.

Still further, when the three-dimensional sensor is provided in the vicinity of the ultrasonic probe 13 and the detected signal is wirelessly transmitted, the nondestructive inspection can be limitedly performed to only a portion required to be particularly inspected, so that it becomes possible to perform an extremely simple inspection.

Still furthermore, when the inspection data obtained at every stage after the flight services are recorded and filed, the inspection data obtained at the present stage can be compared in detail with the former inspection data, so that it becomes possible to accurately predict and evaluate the influence of fatigue of the aircraft body 1.

[Second Embodiment]

Next, a second embodiment of the present invention will be explained with reference to the accompanying FIG. 7 to FIG. 9. FIG. 7A is a plan view showing an example of an apparatus for inspecting an aircraft body according to a second embodiment of the present invention in which two bogies 11 and 11 are arranged in parallel, while the laser system and the ultrasonic probe are mounted on a horizontally transferring mechanism 40 capable of transferring in a horizontal direction. FIG. 7B is a side view of

the apparatus shown in FIG. 7A.

Further, in an ultrasonic nondestructive inspection apparatus for inspecting the aircraft body as specified in claim 2, a plurality of inspection vehicles can be connected to each other in accordance with the conditions of the inspection area for the aircraft body 1 by the action of the horizontally transferring mechanism, so that it becomes possible to efficiently obtain the inspection data from wider surface range of the aircraft body 1 even if a setting-up operation for the inspection is performed only once, thus being advantageous, and the efficiency of the inspection operation can be greatly increased.

FIG. 8 and FIG. 9 are plan views respectively showing an example of the apparatus for inspecting an aircraft body according to the second embodiment of the present invention in which the apparatus comprises two or four inspection vehicles 10 each having a structure shown in FIG. 7. According to this structure of the apparatus, the inspecting operation can be simultaneously performed to a plurality of surface portions of the aircraft body 1, so that an entire inspection time can be shortened and the efficiency of the inspecting operation can be greatly increased.

By the way, although above first and second embodiments have been explained by taking the example comprising the inspection vehicle 10 provided with the wheels that are movable in any directions in a horizontal plane, it is also possible to adopt a bogie-type inspection vehicle capable of traveling on a rail or

track arranged on ground in parallel with the aircraft body 1.

WHAT IS CLAIMED IS:

1. An apparatus for inspecting an aircraft body comprising:

an inspection vehicle traveling to every direction in a horizontal plane;

a laser device mounted on the inspection vehicle and configured to radiate a laser beam to an aircraft body to be inspected and to receive a reflected laser beam from the aircraft body;

an ultrasonic probe mounted on the inspection vehicle and configured to emit an ultrasonic wave to the aircraft body and to receive a reflected ultrasonic wave from the aircraft body; and

a control device configured to control the traveling of the inspection vehicle in response to a signal transmitted from the laser device and to display ultrasonic inspection data of the aircraft body in response to a signal transmitted from the ultrasonic probe.

2. The apparatus for inspecting an aircraft body according to claim 1, wherein the ultrasonic probe is provided for a tip end portion of a multi-spindled robot arm.

3. The apparatus for inspecting an aircraft body according to claim 1, wherein the inspection vehicle includes a magnetic sensor which is responsive to a magnetic tape disposed on a ground.

4. The apparatus for inspecting an aircraft body according to claim 1, wherein the ultrasonic probe includes a contact type touch sensor in a vicinity of the ultrasonic probe, the touch sensor being configured to prevent an influence of curved surface of the aircraft body from mixing into the ultrasonic inspection data.

5. The apparatus for inspecting an aircraft body according to claim 1, wherein the ultrasonic probe includes a three-dimensional sensor in a vicinity of the ultrasonic probe, and the control device is configured to display, in combination, the ultrasonic inspection data together with positional data obtained from the three-dimensional sensor.

6. The apparatus for inspecting an aircraft body according to claim 1, wherein the control device is configured to analyze and evaluate a fatigue caused by a flight operation of the aircraft body by comparing the obtained ultrasonic inspection data with those obtained at proceeding time before the flight operation.

7. The apparatus for inspecting an aircraft body according to claim 1, wherein the control device is arranged to a position apart from the aircraft body, and the control device is configured to wirelessly receive a signal transmitted from the ultrasonic probe.

8. The apparatus for inspecting an aircraft body according to claim 1, wherein a plurality of inspection vehicles are connected to each other by means of a horizontally transferring mechanism, and the ultrasonic probe and the laser device are mounted on the horizontally transferring mechanism.

9. A method of inspecting an aircraft body comprising the steps of:

preparing an inspection vehicle traveling to every direction in a horizontal plane and being mounted with a laser device and an ultrasonic probe;

radiating a laser beam to the aircraft body to be inspected, the laser beam being generated by the laser device mounted on the inspection vehicle;

determining a position of the inspection vehicle with respect to the aircraft body by utilizing the laser beam; and

performing an ultrasonic inspection to the aircraft body by the ultrasonic probe mounted on the inspection vehicle.