Moreover, the proposed solutions do not enable sufficiently accurate location in space to guarantee a homogeneous renovation treatment over all the area of a ship's hull to be renovated.

Finally, it is far from certain that of all the proposed solutions at least one can be implemented in a completely autonomous manner over all the area of a ship's hull, that is to say with no human intervention.

There is therefore a need to improve the robots intended for the renovation by removal of paint films and/or by painting walls of large area and/or of great height, more particularly hulls of ships in dry dock, that alleviates the aforementioned disadvantages, in particular in order to reduce considerably the duration of intervention and the attendant costs, reducing the difficulty of the works, and increasing the effectiveness and the homogeneity of the surface treatments over all the area of the walls to be renovated.

The aim of the invention is to address this requirement at least in part.

Summary ~~of the invention~~

To this end, in one of its aspects, the ~~invention~~ present disclosure refers to~~concerns~~ a robot for renovation by removal of paint films and/or coating with paint and/or inspection of a wall of large area and/or of great height, comprising:

- a telescopic aerial lift comprising as elements:
  - a mobile base,
  - a turret mounted to rotate on the base about a first axis,
  - a telescopic boom mounted to rotate on the turret about a second axis, the boom being telescopic along a third axis,
  - a platform mounted to rotate at the mobile end of the telescopic boom about a fourth axis,
- a tool carrier, adapted to carry a renovation and/or inspection tool, the tool carrier being mounted to rotate on the platform about three mutually orthogonal axes, respectively a fifth axis, a sixth axis and a seventh axis, and to rotate on the platform about an eighth axis;
- a plurality of sensors comprising:
  - a first angular sensor adapted to measure the angular position of the turret relative to the base;
  - a second angular sensor adapted to measure the angular position of the boom relative to the turret;

- a linear displacement sensor adapted to measure the telescopic deployment of the boom;
- at least two distance measurement sensors each adapted to measure a distance of a point on the tool carrier relative to the wall to be renovated and/or inspected;
- an inclination sensor adapted to measure the inclination of the tool carrier relative at least to the horizontal;

- a command and control unit connected to the plurality of sensors and to the means for the displacement of the elements of the aerial lift and for the displacement of the tool carrier along the first to eighth axes, the command and control unit being adapted to move the elements of the aerial lift and the tool carrier automatically along one and/or another of the first to eighth axes, as a function of information delivered by the plurality of sensors and in accordance with a predefined sequence of renovation and/or inspection of zones of the wall without the mobile base of the aerial lift having to be moved.

The ~~invention~~ present disclosure therefore consists essentially in a robot based on an aerial lift that can be of standard type instrumented by means of a plurality of sensors that precisely compensate the absence of instrumentation provided by the aerial lift manufacturers, in order to be able to supply to the command and control unit the information useful for the determination in real time of the very precise location in space of the platform of the aerial lift and therefore of the tool carrier mounted on the platform.

The command and control unit is therefore able to execute the instructions for movement with respect to the various axes of the aerial lift as a function of the precise knowledge in real time of the position in space.

As described in detail hereinafter, if necessary the robots in accordance with the invention can advantageously integrate devices for compensating operating play of the aerial lift in order to guarantee a flexibility and an accuracy of movement of the tool carrier and therefore of an inspection or working (removal of paint films, painting) tool compatible with the intended renovation of the hulls of ships.

When the inventors began to take an interest in the design of a robotic system that would be able to carry out the removal of paint films and the painting of a ship's hull, they drew up an inventory of the existing solutions, in particular those described in the patents and patent applications mentioned above.

For reasons of cost, ineffectiveness or complexity of implementation, they then rapidly moved away from the solutions that necessitate an infrastructure dedicated to each dry dock (solutions with integral rails and/or scaffolding along the hulls) or use a completely new machine (platform of specific design) or are based on existing equipment (a six-axis robot at the end of an aerial lift).

The inventors therefore thought of robotizing an existing standard aerial lift and therefore drew up an inventory of aerial lift types to check which was the most appropriate for the application.

Articulated boom aerial lifts do not seem appropriate, in particular for the following reasons:

- the number of connecting axes is very high to the point where too much flexibility is introduced at the end of the aerial lift;
- command and control laws for automated operation can become very complex.

Scissors type aerial lifts have only an axis of vertical movement, and thus cannot in any case address the requirements of the intended renovation.

Telescopic aerial lifts are by their very nature intended to carry out works on structures of great height. Moreover, the telescopic boom of aerial lifts is extremely rigid and the simplicity of its kinematics facilitates the automation of movements.

The inventors therefore opted for this type of aerial lift.

They then gave careful thought to instrumenting a standard aerial lift by means of a plurality of sensors that precisely compensate the absence of instrumentation provided by the aerial lift manufacturers.

In accordance with one advantageous example variant, the first angular sensor is an absolute optical coder comprising an optical barcode reader fixed relative to the turret, and a ring fixed relative to the mobile base and the periphery of which supports an annular band comprising a plurality of distinct and mutually adjacent barcodes, arranged facing the optical reader so that during a rotation of the turret relative to the mobile base the light beam from the reader intercepts at least one portion of one of the barcodes in order to determine the angular position of the turret.

The arrangement of the annular band relative to the barcode reader is preferably such that the light beam intercepts at least three portions of distinct barcodes.

In accordance with another advantageous example variant, the second angular sensor is an absolute cable coder comprising a coder fixed to the mobile turret and a cable mechanism comprising a drum

fixed to the mobile turret about which is wound a cable the free end of which is fixed to one of the elements of the telescopic boom.

In accordance with another advantageous example variant, the linear displacement sensor is an absolute cable coder comprising a coder fixed to the end of the fixed element of the telescopic boom and a cable mechanism comprising a drum fixed to end of the fixed element of the telescopic boom and about which is wound a cable the free end of which is fixed to the end of the mobile element of the telescopic boom with the greatest deployment.

In accordance with another advantageous example variant, the at least two distance measurement sensors are two first laser rangefinders fixed at a distance from one another to the tool carrier to measure two distances between the tool carrier and the wall to be renovated and/or inspected. An alternative that may equally be envisaged is an absolute coder installed in the connection between the platform and the telescopic boom.

Another laser rangefinder is preferably fixed to the center of the tool carrier while the two first rangefinders are fixed to the lower and upper ends of the tool carrier.

In accordance with another advantageous example variant, the inclination sensor is a two-dimensional sensor fixed to the platform and adapted to measure the inclination of the latter on two distinct axes.

In accordance with one advantageous example~~embodiment~~, the robot comprises a device for compensation of the mechanical play of the toothed ring for orienting the mobile turret, the device comprising, in addition to the toothed ring and the motor for driving the latter in rotation, at least one gear meshing with the toothed ring and one motor for driving the gear in a rotation direction opposite to that of the toothed ring.

In accordance with another advantageous example~~embodiment~~, the robot comprises a device for compensation of the mechanical play between the platform and the telescopic boom, the device comprising a connection assembly between the platform and the telescopic boom, the connecting assembly comprising a first connecting element fixed with respect to the fourth axis and a second connecting element fixed to the platform, the first and second connecting elements being articulated to one another by an orientation ring adapted to be caused to rotate by means of a cylinder, preferably of electrical type, one end of which is fixed to the first connecting element and the other end of which is fixed to the second connecting element.

In accordance with another advantageous example~~embodiment~~, the command and control unit comprises an automatic command and controller for the aerial lift connected to each of the plurality of sensors, preferably by a ADC bus, a first computer termed the aerial lift computer connected to the aerial lift automatic controller and a second computer termed the robot computer preferably connected over an Ethernet connection to the aerial lift automatic controller, the robot computer being adapted to send its command and control instructions to the aerial lift automatic controller that is itself adapted to send its command and control instructions to the aerial lift computer that command and controls the movement of the components of the aerial lift and of the tool carrier with respect to one and/or another of the first to eighth axes.

In accordance with another advantageous example~~embodiment~~, the mobile base comprises a movement in translation motor defining a ninth axis and at least one steerable axle defining a tenth axis.

The command and control unit is advantageously adapted to move the mobile base automatically with respect to one and/or the other of the ninth and tenth axes once the predefined sequence has been completed.

In accordance with another advantageous ~~embodiment~~example, the platform pivots relative to the mobile end of the telescopic boom about a pivot axis defining an eleventh axis orthogonal to the fourth axis. In the context of the ~~invention~~present dislcosure, it goes without saying that this eleventh axis may be independent of the ninth and tenth axes and vice versa. Thus, by convention, in the configuration in which the mobile base does not define the ninth axis and the tenth axis, then the axis of pivoting of the platform relative to the mobile end of the boom becomes the ninth axis.

In accordance with one advantageous example feature, the tool carrier is adapted to carry an abrasive blasting nozzle provided with an aspiration hood for recycling the abrasive or a nozzle for spraying water at high pressure with a hood for re-aspiration of the sprayed water.

The ~~invention~~ present disclosure further refers in another aspect to~~equally has for object~~ a method of operating a robot as described in the above aspect along a wall of large area and/or of great height, comprising the following steps carried out automatically by the command and control unit:

i/ positioning the platform and therefore the tool carrier carrying the renovation tool at a given point of the wall;

ii/ moving the tool carrier along a first vertical band along the wall defining a first renovation pass;

iii/ once the first renovation pass has been completed, automatic descent by raising and/or telescoping the platform over a height corresponding to the first working pass less a predefined area of overlap;

iv/ reiterating steps ii/ and iii/ in accordance with one or more working passes in addition to the first, until the platform reaches its extreme low position;

v/ the command and control unit evaluating if a second band parallel to the first can be swept by the tool carrier without having to move the mobile base.

- if the evaluation in step v/ is positive, then positioning the platform at a given point on the second band and then reiterating steps ii/ to iv/ in the second band;

- if the evaluation in step v/ is negative, then stopping the renovation pending movement of the mobile base.

In other words the operating method in accordance with the ~~invention~~ present disclosure is sequenced on the basis of information delivered by the sensors fitted together with the calibration or correction thereof in order to produce a vertical working (cleaning, removal of paint films or painting in the case of a ship's hull) band along the wall to be renovated.

The command and control unit of the robot in accordance with the present disclosure ~~invention~~ can work either in spot mode (specific zones to be treated) or by continuous treatment of a large area of the hull of a ship. To do this, in the method in accordance with the present disclosure~~invention~~, the command and control unit processes a succession of vertical bands that it sequences automatically.

The number of vertical bands that a robot can treat is evaluated taking into account intrinsic technical characteristics of turret orientation, boom telescoping, platform orientation.

Equally, the evaluation takes into consideration the necessity for an overlap between bands.

On each positioning of the platform and therefore of the tool carrier relative to the wall to be renovated, the horizontality of the platform as well as its orientation are corrected, in order to obtain the same distances on the two distance measurement sensors.

If the surface of the wall is vertical, then these corrections suffice. In the situation where the hull is not vertical (bottom swelling or curve for example in the case of a ship's hull), when the two sensors are at equal distances from the wall, their value may be greater than or less than on the preceding pass. To correct this difference the angle of rotation of the turret is corrected.

A result of the correction of this angle will be to modify the horizontal distance between the

turret axis and the wall to be renovated, which must not evolve so as to remain on the initial vertical. The effect of this angle modification must therefore be calculated by the command and control unit to define a new boom telescoping set point.

The subsequent movement of the mobile base can then also be effected autonomously with respect to the ninth and tenth axes of the aerial lift.

The present disclosure ~~invention~~ finally refers in another aspect to~~has for object~~ the use of the robot as described in the above aspects for the renovation of a ship's hull including removal of paint films, preferably by spraying abrasive or removal of paint films with water, and where necessary including painting.

Other advantages and features of the invention will emerge more clearly on reading the detailed description of embodiments of the invention given by way of nonlimiting illustration with reference to the following figures.

Brief description of the drawings

[Fig 1] is a schematic perspective view of a robot in accordance with the invention intended for the inspection and the renovation of a wall of large area and of great height, figure 1 showing the robot in a configuration for renovation of a ship's hull in dry dock.

[Fig 2] is another perspective view of the robot from figure 1, figure 2 showing all of the axes of movement of the components of the aerial lift of the robot as well as of the tool carrier that is carried by the platform of the aerial lift.

[Fig 3] is another schematic perspective view of a robot in accordance with the invention, figure 3 showing a first embodiment of the tool carrier.

[Fig 3A] is a view of a detail from figure 3.

[Fig 4] repeats figure 3A in perspective view from the front and shows one of various positions assumed by the tool carrier and a removal of paint films tool carried by the tool carrier.

[Fig 5] repeats figure 3A in perspective view from the front and shows one of the various positions assumed by the tool carrier and a removal of paint films tool carried by the tool carrier.

[Fig 6] repeats figure 3A in perspective view from the front and shows one of the various positions assumed by the tool carrier and a removal of paint films tool carried by the tool carrier.

[Fig 7] is another schematic perspective view of a part of a robot in accordance with the invention, figure 7 showing a second embodiment of the tool carrier.

Claims

1. A robot (1) for renovation by removal of paint films and/or coating with paint and/or inspection of a wall of large area and/or of great height, comprising:

- a telescopic aerial lift (2) comprising as elements:

  • a mobile base (20),

  • a turret (23) mounted to rotate on the base about a first axis (Axis 1),

  • a telescopic boom (24) mounted to rotate on the turret about a second axis (Axis 2), the boom being telescopic along a third axis (Axis 3),

  • a platform (25) mounted to rotate at the mobile end of the telescopic boom about a fourth axis (Axis 4),

- a tool carrier (3), adapted to carry a renovation and/or inspection tool (4), the tool carrier being mounted to rotate on the platform about three mutually orthogonal axes, respectively a fifth axis (Axis 5), a sixth axis (Axis 6) and a seventh axis (Axis 7), and to rotate on the platform about an eighth axis (Axis 8);

- a plurality of sensors comprising:

  • a first angular sensor (5) adapted to measure the angular position of the turret relative to the base;

  • a second angular sensor (6) adapted to measure the angular position of the boom relative to the turret;

  • a linear displacement sensor (7) adapted to measure the telescopic deployment of the boom;

  • at least two distance measurement sensors (80, 81) each adapted to measure a distance of a point on the tool carrier relative to the wall to be renovated and/or inspected;

  • an inclination sensor (9) adapted to measure the inclination of the tool carrier relative at least to the horizontal;

- a command and control unit (12) connected to the plurality of sensors and to the means for the displacement of the elements of the aerial lift and for the displacement of the tool carrier along the first to eighth axes, the command and control unit being adapted to move the elements of the aerial lift and the tool carrier automatically along one and/or another of the first to eighth axes, as a function of information delivered by the plurality of sensors and in accordance with a predefined sequence of renovation and/or inspection of zones of the wall without the mobile base of the aerial lift having to be moved.

2. The robot (1) as claimed in claim 1, the first angular sensor being an absolute optical coder (5) comprising an optical barcode reader (50) fixed relative to the turret, and a ring (51) fixed relative to the mobile base and the periphery of which supports an annular band (52) comprising a plurality of distinct and mutually adjacent barcodes (53), arranged facing the optical reader so that during a rotation of the turret relative to the mobile base the light beam from the reader intercepts at least one portion of one of the barcodes in order to determine the angular position of the turret.

3. The robot (1) as claimed in claim 2, the arrangement of the annular band relative to the barcode reader being such that the light beam intercepts at least three portions of distinct barcodes.

4. The robot (1) as claimed in ~~any one of the preceding~~ claim 1~~s~~, the second angular sensor being an absolute cable coder (6) comprising a coder (60) fixed to the mobile turret and a cable mechanism (61) comprising a drum fixed to the mobile turret about which is wound a cable (62) the free end of which is fixed to one of the elements of the telescopic boom.

5. The robot (1) as claimed in ~~any one of the preceding claims~~claim 1, the linear displacement sensor being an absolute cable coder (7) comprising a coder fixed to the end of the fixed element of the telescopic boom and a cable mechanism comprising a drum fixed to the end of the fixed element of the telescopic boom and around which is wound a cable (70) the free end (71) of which is fixed to the end of the greatest deployment mobile element of the telescopic boom.

6. The robot (1) as claimed in ~~any one of the preceding~~ claim~~s~~ 1, the at least two distance measurement sensors being two first laser rangefinders (80, 81) fixed at a distance from one another to the tool carrier to measure two distances between the tool carrier and the wall to be renovated and/or inspected.

7. The robot (1) as claimed in claim 6, comprising another laser rangefinder (82) fixed to the center of the tool carrier (3) while the two first rangefinders are fixed to the lower and upper ends of the tool carrier.

8. The robot (1) as claimed in ~~any one of the preceding~~ claim~~s~~ 1, the inclination sensor being a two-dimensional sensor (9) fixed to the platform and adapted to measure the inclination of the latter on two distinct axes.

9. The robot (1) as claimed in ~~any one of the preceding~~ claim~~s~~ 1, comprising a device (10) for compensation of the mechanical play of the toothed ring (230) for orienting the mobile turret, the device comprising, in addition to the toothed ring and the motor (231) for driving the latter in

rotation, at least one gear (102) meshing with the toothed ring (230) and one motor (101) for driving the gear in a rotation direction opposite to that of the toothed ring.

10. The robot (1) as claimed in ~~any one of the preceding~~ claim~~s~~ 1, comprising a device (11) for compensation of the mechanical play between the platform and the telescopic boom, the device comprising a connection assembly between the platform and the telescopic boom, the connecting assembly comprising a first connecting element (111) [fixed with respect to the fourth axis] and a second connecting element (112) [fixed with respect to the platform], the first and second connecting elements being articulated to one another by an orientation ring (113) adapted to be caused to rotate by means of a cylinder (114), preferably of electrical type, one end of which is fixed to the first connecting element and the other end of which is fixed to the second connecting element.

11. The robot (1) as claimed in ~~any one of the preceding~~ claim~~s~~ 1, the command and control unit (12) comprising an automatic controller (120) for the aerial lift connected to each of the plurality of sensors, preferably by an ADC bus, a first computer termed the aerial lift computer (121) connected to the aerial lift automatic controller and a second computer termed the robot computer (122) preferably connected over an Ethernet connection to the aerial lift automatic controller, the robot computer being adapted to send its command and control instructions to the aerial lift automatic controller that is itself adapted to send its command and control instructions to the aerial lift computer that command and controls the movement of the components of the aerial lift and of the tool carrier with respect to one and/or another of the first to eighth axes.

12. The robot (1) as claimed in ~~any one of the preceding~~ claim~~s~~ 1, the mobile base (20) comprising a movement in translation motor defining a ninth axis (Axis 9) and at least one steerable axle defining a tenth axis (Axis 10).

13. The robot (1) as claimed in claim 12, the command and control unit being adapted to move the mobile base automatically with respect to one and/or the other of the ninth and tenth axes once the predefined sequence has been completed.

14. The robot (1) as claimed in ~~any one of the preceding~~ claim~~s~~ 1, the platform (25) pivoting relative to the mobile end of the telescopic boom about a pivot axis (241) defining an eleventh axis (Axis 11) orthogonal to the fourth axis (Axis 4).

15. The robot (1) as claimed in ~~any one of the preceding~~ claim~~s~~ 1, the tool carrier being adapted to carry an abrasive blasting nozzle (4) provided with an aspiration hood for recycling the abrasive or a nozzle for spraying water at high pressure with a hood for respiration of the sprayed water.

16. A method of operating a robot as claimed in ~~any one of the preceding~~ claim~~s~~ 1 along a wall of large area and/or of great height, comprising the following steps carried out automatically by the command and control unit:

i/ positioning the platform and therefore the tool carrier carrying the renovation tool at a given point of the wall;

ii/ moving the tool carrier along a first vertical band along the wall defining a first renovation pass;

iii/ once the first renovation pass has been completed, automatic descent by raising and/or telescoping the platform over a height corresponding to the first working pass less a predefined area of overlap;

iv/ reiterating steps ii/ and iii/ in accordance with one or more working passes in addition to the first, until the platform reaches its extreme low position;

v/ the command and control unit evaluating if a second band parallel to the first can be swept by the tool carrier without having to move the mobile base.

- if the evaluation in step v/ is positive, then positioning the platform at a given point on the second band and then reiterating steps ii/ to iv/ in the second band;

- if the evaluation in step v/ is negative, then stopping the renovation pending movement of the mobile base.

17. Use of the robot as claimed in ~~any one of the preceding~~ claim~~s~~ 1 for the renovation of a ship's hull by removal of paint films, preferably by spraying abrasive or removal of paint films with water, and where necessary with painting.