

Description

Title: Robot for renovation by pickling and/or paint coating, and/or the inspection of a large-surface and/or large-height wall, associated operating method and application to pickling and painting ship hulls.

5 Technical field

The present invention concerns the general field of inspection and/or renovation by surface treatment and painting of large structures/objects.

It more particularly concerns the field of the renovation by removal of paint films and where necessary painting a wall of large area and/or of great height, in particular hulls of ships.

10 By “wall of large area and/or great height” is meant any object the inspection and/or the renovation of which cannot be effected by a single person and usually necessitate(s) at least the use of scaffolding and/or any handling means for moving a person.

The present invention aims more particularly to propose an autonomous robot intended for the renovation and/or inspection of such a wall, in order to reduce the intervention times and the
15 attendant costs.

Although described with reference to an advantageous application of renovating a ship’s hull, the invention applies to any robot intended for any type of inspection and/or repair works on large structures.

Prior art

20 It is necessary to maintain the hulls of ships regularly after a period in service, generally a maintenance operation involving a plurality of works intended to give them (back) the required esthetic appearance, such as rubbing down, abrasive blasting, surface treatment and painting.

By virtue of its obligatory nature, this maintenance operation imposes installing the ships in dry dock.

25 In substance, it is a matter of eliminating the existing exterior coating and any oxidation and to replace them with new.

Maintenance or renovation generally consists in carrying out a surface preparation appropriate to the application of a new coat of paint. This preparation can for example consist in removal of paint films with spraying of abrasive, also generally known as abrasive blasting, or spraying with

water at ultra-high pressure (UHP) that enables creation of a certain surface roughness for the adhesion and the application of a new coat of paint.

Each given ship renovation process step must be carried out, and with extreme care in order to prevent the presence of defects that can considerably degrade the final esthetic quality.

- 5 Although numerous and varied in their constraints and their implementations, all shipyards executing a process of renovation of a ship's hull are confronted with the same challenges: high repair costs, long interruptions of service, major impact on the ship, personnel safety and the effectiveness of the repair.

10 Until now, the various renovation steps are usually carried out manually by operatives or with the aid of a plurality of appropriate tools for removing paint films and spraying paint on the required area of the hull.

These manual steps have a certain number of major drawbacks.

15 First of all, each of them requires a long execution time which impacts on the final cost of the work. Thus each step must be relatively precise because the tools used, for example for the removal of paint films, ultra-high pressure (UHP) water lances, at around 3000 bar, or abrasive blasting lances, have a relatively limited active area and require the continuous close attention of the operator. A result of this is that these operations can take a considerable time both for the work and for the checks, all the more so in that the areas of hulls of ships are very large.

20 Then, the effectiveness of the steps depends greatly on the competence of the operatives that carry them out.

Also, where the painting step is concerned, the latter is carried out with the aid of a paint spraying tool that generates atomization of the paint particles, some of which do not adhere to the surface to be painted, spreading into the environment. Given that the anti-corrosion paints used for these applications generally contain toxic or polluting substances, it is readily
25 understandable how spreading them can be harmful to the environment and to persons working in the vicinity of the painting zones.

On this subject, recent community standards provide increasingly more restrictive measures where the emission of such substances into the environment is concerned.

30 The applicant has therefore wished to automate this maintenance or renovation of these hulls of ships and to employ a robot able to carry out these renovation operations.

However, the specifications imposed for a robot of this kind are strict and voluminous, in particular because of the high constraints intrinsic to moving ships into dry dock.

The inventors of the present invention have therefore drawn up an inventory of the existing solutions.

- 5 They came first to the conclusion that none of the existing robotic or mechanized systems were able to satisfy all the requirements for the renovation of hulls of ships.

Some devices for painting hulls of ships or the like are known from patent documents.

- WO01/34309 describes a device for spraying paint onto a ship's hull in dry dock comprising a row of spray nozzles housed in a hood mounted at the end of a telescopic arm itself mounted to
10 pivot on a chassis that can be moved in translation on a rail along the hull.

US5398632 proposes a scaffolding system installed on the bottom of the dock around the hull with baskets that can be moved in height and close to/away from the hull and in which painters can stand.

- US4890567 describes a cleaning system with a cleaning head that can be moved and be fixed to
15 the hull of ships by electromagnetic tracks and that incorporates means for cleaning by application of ultrasound.

EP2090506B1 discloses a platform with two sets of wheels and a double lifting platform of the scissors type supporting an elongate table provided with a rail on which a six-axis robot carrying a paint spray gun is able to slide to paint the surface of a ship's hull.

- 20 CN105643587 discloses a system for painting hulls of ships with a six-axis robot carrying the painting tool mounted at the end of an articulated arm of an aerial lift that moves on the bottom of the dock.

- CN2019158233 discloses a painting robot system of the type moved by cables along hulls of ships in which the chassis supporting the drive motors and the cables are installed in situ in and
25 around the dry dock, the heightwise movement of the paint spraying nozzles being imparted by cables while the horizontal one is imparted by a telescopic arm supporting said nozzles.

CN108942897 discloses a system for painting hulls of ships comprising a robotic paint head moved by cable along hulls of ships, the cables being fixed to two bogies, one moving on the ground and the other above the ship.

CN108313237 discloses a system for abrasive blasting hulls of ships comprising a robot that is moved by a winch on board the ship and that is fixed to the surface of the hull by suckers.

CN107253147 and CN107081771 each describe a system for removal of paint films by abrasive blasting comprising an abrasive blasting robot that moves by rolling on the hull on the ship and is retained by permanent magnets, with an anchor point on the hull and a cable winch for the movement.

KR101444392B1 concerns a paint application system with a six-axis robot mounted at the end of a crane boom.

WO2012/080448 discloses a complete maintenance system (UHP cleaning, painting) with a scaffolding tower near the hull on which a telescopic arm system that supports the working tool can move vertically.

WO2010/057942 discloses a system analogous to WO2012/080448, with the essential differences that the scaffolding tower carries a plurality of working cabins one of which is command and controlled directly by a person inside it and that carries an articulated arm supporting the working tools.

WO2018/209367 describes a system of rails assembled together to move along a ship's hull assemblies for maintenance (cleaning, painting) of the hull.

EP2618942B1 discloses the use of a six-axis robot that carries a painting spray gun and is supported by the aerial lift of an aerial work platform for painting hulls of ships in dry dock. The aerial lift is equipped with distance sensors for measuring the distance of the latter relative to the hull surface to be painted, the operation of the sensors being slaved to the command and control unit for movement of the platform. Also, the proposed system necessarily comprises aspiration of air along the surface to be painted and the command and control process enables adjustment of the distance between the aerial lift and the surface to be painted in order to optimize the aspirated air flow rate.

None of the proposed solutions can be at one and the same time fast, cheap and effective for eliminating tenacious defects on the surface of the hulls, more particularly those resulting from corrosion thereof, nor for the application of a homogeneous coating over all the same area of a ship's hull, whatever its profile (flat, concave, convex).

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 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 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 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 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 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 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 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 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 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 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
 5 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.

10 In accordance with another advantageous 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.

15 In accordance with another advantageous embodiment, 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, 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
 20 pivoting of the platform relative to the mobile end of the boom becomes the ninth axis.

In accordance with one advantageous 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 equally has for object a method of operating a robot as described above along a
 25 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
 30 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 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 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 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 invention finally has for object the use of the robot as described above 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.

[Fig 8] is a photographic reproduction showing the arrangement of an absolute optical coder for the measurement of the angular position of the turret relative to the mobile base of the aerial lift.

[Fig 8A] is a view of a detail from figure 8.

[Fig 9] is a schematic view illustrating the operating principle of the absolute optical coder according to figure 8.

[Fig 10] is a photographic reproduction showing the arrangement of an absolute cable coder for the measurement of the angular position of the telescopic boom relative to the turret of the aerial lift.

[Fig 11] is another photographic reproduction showing the arrangement of an absolute cable coder for the measurement of the angular position of the telescopic boom relative to the turret of the nacelle.

[Fig 12] is a photographic reproduction showing the arrangement of an absolute cable coder for the measurement of the telescoping of the boom.

[Fig 13] is a schematic side view showing the platform and the tool carrier of a robot in accordance with the invention in a renovation configuration close to a ship's hull with a curved profile, figure 13 further illustrating the measurement of distance by each of the two rangefinders between a point on the tool carrier and the hull to be renovated.

[Fig 14] is a photographic reproduction showing the arrangement on the platform of a robot in accordance with the invention of an inclination sensor for measuring the inclination of the tool carrier relative at least to the horizontal.

[Fig 15] is a schematic view of one embodiment of the lower part of a robotic aerial lift in accordance with the invention, showing as if by transparency the arrangement of a device for compensating mechanical play of the ring for orienting the turret relative to the mobile base.

[Fig 15A] is a view of a detail from figure 15.

[Fig 16] is a schematic view of one embodiment of the connection between the telescopic boom and the platform of a robot aerial lift in accordance with the invention, showing the arrangement of a device for compensating mechanical play between the platform and the telescopic boom.

[Fig 17] is a synoptic view of the connections between the position and distance sensors of the robot in accordance with the invention with the computers and the automatic controller of the command and control unit as well as the connections between the latter.

[Fig 18] illustrates schematically as a function of the movement characteristics of a first category of commercial aerial lifts the vertical renovation bands that it is envisaged to treat in accordance with the method of operating the robot in accordance with the invention.

[Fig 19] illustrates schematically as a function of the movement characteristics of a second category of commercial aerial lifts the vertical renovation bands that it is envisaged to treat in accordance with the method of operating the robot in accordance with the invention.

Detailed description

It is hereby specified that throughout the present application the terms “below”, “above”, “low”, “high”, “lower” and “upper” refer to an operating configuration of an aerial lift of a robot in accordance with the invention. Thus, for example, the extreme uppermost position of the platform of the aerial lift is the greatest height that it is able to reach with the maximum raising of the boom combined with the maximum deployment of the latter.

There has been represented in figure 1 a robot in accordance with the invention in a configuration for inspection by video camera and/or for renovation with removal of paint films by abrasive blasting or spraying of water at high pressure followed where applicable with painting a hull C of a ship in dry dock in a shipyard, in the context of maintenance of the ship.

As shown in figure 2, the robot 1 comprises first of all a telescopic aerial lift 2. This aerial lift 2 comprises in a manner known in itself, respectively, a mobile base 20 with two axles 21, 22 at least one of which is a pivoting axle forming a steerable axle, 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 23 about a second axis “Axis 2”, the boom being telescopic along a third axis “Axis 3”, a platform 25 also known as a basket mounted to rotate at the mobile end of the telescopic boom about a fourth axis “Axis 4”.

In accordance with the invention, a tool carrier 3 is mounted to move in rotation 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 in rotation on the platform about an eighth axis “Axis 8”.

A tool 4 for renovation and/or inspection of the ship’s hull to be renovated is fixed to this tool carrier 3. For the removal of paint films operations the tool 4 is preferably an abrasive blasting nozzle provided with a suction hood for recycling the abrasive or a nozzle for spraying water at high pressure with a hood for re-aspiration of the sprayed water.

A number of embodiments may be envisaged for mounting the tool carrier 3 on the platform 25 of the aerial lift 2.

In accordance with the first embodiment illustrated in figures 3 to 6, the tool carrier 3 is mounted on a two-axis Cartesian robot 30 and one end of the gantry is mounted to pivot on the platform 25.

To be more precise, as can be seen in figures 3 to 6, the movement in translation of the tool carrier 3 along the two axes of the Cartesian robot is driven by two independent motors 31, 32 fixed to the gantry, while the pivoting of the gantry 30 relative to the platform 25 is driven by two cylinders 33, 34, preferably of electrical type, articulated between the gantry of the Cartesian robot 30 and the platform 25.

The movements of the two-axis Cartesian robot 30 therefore generate the movements of the tool carrier 3 along Axis 5 and Axis 6 while the pivoting of its gantry generates the movement along Axis 7 and Axis 8.

A second embodiment is illustrated in figure 7. Two independent motors 35, 36 each drive a lead screw and nut system 37, 38 along Axis 5 and Axis 6. The tool 4 is carried by the lead screw and nut system along Axis 6 on a swinging arm 39 driven in rotation by another independent motor 390. The rotation of this swinging arm generates the movement along Axis 7 and Axis 8.

The robot 1 in accordance with the invention is moreover instrumented by a plurality of sensors that accurately compensate the absence of instrumentation provided by aerial lift manufacturers in order to position the tool carrier 3 and therefore the tool 4 in space with very great accuracy.

As illustrated in figures 8, 8A and 9, an absolute optical coder 5 is therefore installed to measure the angular position of the turret 23 relative to the mobile base 20.

Before choosing a sensor of this kind, the inventors drew up an inventory of possible solutions. In fact, the point of rotation of the turret 23 was not concretely accessible because occupied by the rotary seal that enables routing of hydraulic commands between the turret 23 and the mobile base 20. Because of this, it is not possible to install a coder directly on the axis of the turret 23.

Another solution would have been to place a coder at the side of the ring for orienting the turret 23, which would have been driven by a gear itself driven by the external teeth on the orientation ring. Installing this proved not to be simple and wear of the teeth of the ring for orienting the turret was not favorable to a precise measurement. The inventors therefore finally decided to

decorrelate the measurement of rotation proper from the mechanics of the ring for orienting the turret.

The absolute optical coder 5 finally adopted comprises an optical reader 50 fixed to the underside of the turret 23 and a ring 51 fixed relative to the mobile base 20. The periphery of the ring 51 supports an annular band 52 comprising a plurality of distinct barcodes 53 adjacent to one another, arranged facing the optical reader 50 so that during a rotation of the turret relative to the mobile base the light beam from the reader 50 intercepts at least three portions of distinct barcodes, as shown in figure 9. This optical coder 5 therefore makes it possible to obtain absolute information independent of the play in the mechanical parts for orienting the turret 23 relative to the base 20.

The annular band 52 may take the form of an adhesive tape, which has the advantage of being very economical and therefore able to be replaced as often as necessary. There may equally be envisaged by way of an alternative etching the barcodes 53 directly onto the ring 51.

As shown in figures 10 and 11, an absolute cable coder 6 makes it possible to measure the angular position of the boom 24 relative to the turret 23.

The choice of this type of sensor was guided by the fact that it is physically impossible to install a coder on the boom raising axis, and moreover that the kinematics vary from one aerial lift to another and are sometimes complex with a raising pivot point that moves upward and toward the rear relative to the mobile base. The only solution is therefore to have a sensor that moves continuously relative to the raising and to carry out calibration of this measurement relative to the real raising angle. Moreover, a cable coder enables a precise measurement to be obtained whilst being mechanically robust.

The absolute cable coder 6 comprises a coder 60 fixed to the mobile turret and a cable mechanism 61 comprising a drum fixed to the mobile turret and around which is wound a cable 62 the free end of which is fixed to one of the elements of the telescopic boom.

As shown in figure 12, another cable coder 7 is used: it constitutes a linear displacement sensor for measuring the telescopic deployment of the boom 24. The coder 7 comprises a coder, not represented, fixed to the end of the fixed element of the telescopic boom and to a cable mechanism comprising a drum, not represented, 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 mobile element 240 of the telescopic boom 24 with the greatest deployment.

In practise, the inventors found that the deployment of the mobile elements of the telescopic boom forms a slightly concave (downward) curve. Thus for a measurement given by the coder 7, the real distance between the platform 25 and the rotation axis of the boom 24 is less than that measured by the coder 7. The inventors then evaluated the maximum error, which corresponds to a boom completely deployed. Knowing that the evolution of this error is continuous over the telescoping movement and repeatable, the inventors were able in the end to correct the measurement from the coder 7 by calculation.

As shown in figure 13, two laser rangefinders 80, 81 fixed to the ends of the tool carrier 3 each enable measurement of a distance T1, T2 from a point on the frame of the tool carrier 3 relative to the hull of the ship to be renovated and/or inspected. During operation of the robot in accordance with the invention, in the event of a difference between T1 and T2 then the motor 390 for tilting the tool carrier 3 is started up in one direction or the other as a function of the higher value, until $T1=T2$.

A third laser rangefinder 82 may advantageously be fixed to the center of the frame of the tool carrier 3 in order to determine the distance from the tool 4 to the hull C, which is a minimum in the case of a convex curvature and a maximum in the case of a concave curvature.

In ship's hull renovation the frame of reference of the ship is tied to the bottom of the dock, and thus to an *a priori* horizontal surface. It therefore proves primordial to maintain the base of the platform 25 and therefore the support of the tool carrier 3 horizontal.

To do this, as illustrated in figure 14, a two-dimensional sensor 9 is fixed to the platform 25 in order to measure the inclination of the latter with respect to two distinct axes.

All the sensors 5 to 9 that have just been described and that are installed in the telescopic aerial lift 2 and the tool carrier 3 make it possible to be able to supply to the dedicated computer of the command and control unit of the robot in accordance with the invention information useful for determining the location of the tool 4 in space.

In order to guarantee a flexibility and an accuracy of movement of the tool carrier 3 and therefore of the tool 4 compatible with the target renovation of hulls of ships, the robot 1 in

accordance with the invention can advantageously incorporate devices for compensating operating play of the aerial lift 2.

A first mechanical play compensator device 10 is illustrated in figures 15 and 15A: it enables compensation of the play of the toothed ring 230 for orienting the turret 23.

- 5 As can be seen in figures 15 and 15A, the rotation of the turret 23 is driven by a drive motor 231 that drives a gear 232 meshing directly with the toothed ring 230.

The play compensator device 10 comprises a motor 101 for driving at least one gear 102 meshing with the toothed ring 230 but in the opposite rotation direction to the gear 232 driving the toothed ring 230.

- 10 A second mechanical play compensator device 11 is illustrated in figure 16: it enables compensation of the play between the platform 25 and the telescopic boom 24.

This device 11 consists of a connecting assembly added between the platform 25 and the telescopic boom 24. This connecting assembly 11 comprises a first connecting part 110 secured to the shaft 240 defining Axis 4 and a second connecting part 111 secured to the platform 25.

- 15 These two connecting parts 111, 112 are articulated to one another by an orientation ring 113 adapted to be rotated by means of a cylinder 114, preferably of electrical type, one end of which is fixed to the first connecting part 111 and the other end of which is fixed to the second connecting part 112.

- In this figure 16 it can also be seen that the platform 25 is mounted to pivot relative to the end of
20 the boom 24 about a pivot shaft 241 that therefore defines an eleventh axis (Axis 11). This “Axis 11” is orthogonal to Axis 4.

- The robot 1 in accordance with the invention finally comprises a command and control unit 12 connected to the plurality of sensors 5 to 9 and to the means for moving components of the aerial lift and moving the tool carrier with respect to the first to eighth axes, the command and control
25 unit being adapted to move the components of the aerial lift and the tool carrier automatically with respect to 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 20 of the aerial lift needing to be moved.

An advantageous embodiment of the command and control unit 12 is illustrated in figure 17: it comprises an existing automatic controller 120 of the aerial lift connected to each of the plurality of sensors 5, 6, 7, 80, 81, 9. These connections are preferably via an ADC bus.

The existing aerial lift computer 121 is connected to the aerial lift automatic controller 120.

- 5 A second computer, termed the robot computer 122, is preferably connected over an Ethernet connection to the aerial lift automatic controller 120.

In the operation of the robot, the robot computer 122 sends its command and control instructions to the aerial lift automatic controller 120 that itself sends its command and control instructions to the aerial lift computer 121 that command and controls the movement of the components of the
10 aerial lift and of the tool carrier with respect to one and/or another of the first to eighth axes.

The operation of a robot 1 that has just been described comprises the following steps carried out automatically by the command and control unit 12:

- i/ positioning the platform 25 and therefore the tool carrier 3 carrying the renovation tool at a given point of the hull of the ship;
- 15 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;
- 20 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
25 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.

Thus the command and control unit treats a succession of vertical bands that it sequences automatically.

Initially it is not necessary to evaluate the number of bands that can be treated without having to move the mobile base 20 of the aerial lift, that is to say the area that can be treated automatically without intervention by an operator. In the evaluation of the number of bands that can be treated, the necessity for an overlap between bands must be considered.

- 5 Figures 18 and 19 show schematically the evaluation that was done for two different designs of telescopic aerial lift currently on the market.

The mobile base 20 may be moved in an autonomous manner by the command and control unit along Axes 9 and 10 as illustrated in figure 2.

- 10 Other variants and modifications of the robot in accordance with the invention may be envisaged without as such departing from the scope of the invention.

For example, types of sensors other than those described may be used for the measurement instrumentation for the various axes of movement of the components of a telescopic aerial lift and 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:

- 5 • 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),
- 10 • 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);
- 15 - 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;
 - 20 • 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;
 - 25 - 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 claims, 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, 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 claims, 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 claims, 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 claims, 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 claims, 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 claims, 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 claims, 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 claims, 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 claims, 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 claims 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 claims 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.