

EXTERIOR SERVICING APPARATUS

Field of the Invention

5 This invention relates to apparatus or machinery for use in the servicing of the exterior surface of buildings or other structures. It is particularly suited to use on uneven or irregular surfaces, and, in a preferred form, is unmanned.

Background of the Invention

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 The most common form of servicing of a building exterior is the operation of washing. Most usually this is an operation performed on glazing or windows. A very old technique for achieving this, that is still practised today, is to lower workmen, situated in a gondola, down the face of a building, cleaning as they go. There is
15 considerable personal danger associated with such a practice, and on occasions of high wind or rain, the washing operation must cease.

 An early example of unmanned window washing apparatus that operates by lowering a carriage suspended on wire ropes, typically from the building's roof, is
20 shown in US Patent No. 3,344,454 issued to Mikalson on October 3, 1967. This prior art arrangement includes the use of rotating brushes to clean the window surface.

 A more recent form of window washing machine is shown in US Patent No. 5,890,250 issued to Kerr et al on April 6, 1999. Kerr et al similarly teaches a suspended
25 carriage. The carriage has a pair of longitudinally extending brushes which, in conjunction with spray nozzles, are used to clean the window surface, following a vertical path as the carriage is lowered. The carriage operates to clean a complete face of the building's exterior by repeated vertical 'strip-like' paths.

A further example in the prior art is European Patent No. 0 975 254 B1 assigned to Dornier Technologie GmbH & Co. KG. Dornier describes an automated cleaning device that has a suspended carriage from which is mounted a cleaning head which can be located at the desired location of the building surface, within a boundary formed by the carriage, in accordance with two axis control (i.e. height- and width-wise of the window). Once so located, the cleaning head can be adjusted inwardly towards the window for the cleaning operation. The cleaning head is then moved in width-wise strips until the section of the window surface bounded by the carriage has been cleaned. Dornier also discloses an edge search technique so that the corner of the window can be located for commencement of the cleaning operation.

None of these prior art documents is adapted to cope with uneven or irregularly shaped surfaces, however. Additionally, none of these prior art documents contemplate operations other than cleaning.

It is an object of the present invention to overcome the deficiencies with the prior art.

Summary of the Invention

Accordingly, the invention discloses apparatus for use in the servicing of an exterior surface of a structure, comprising:

- a rectilinear outer frame adapted to be suspended from a supporting structure and raisable and lowerable by hoisting means;
- anchoring devices located at or near the corners of one face of said outer frame, and extending away therefrom, said anchoring devices being independently operable to extend laterally towards the surface to be serviced, and having sensors therewith to sense proximity of said surface;
- an inner frame mounted from said outer frame in a manner to be controllably moveable by one or more actuators laterally of the outer frame, said inner frame also

being controllably moveable by one or more actuators vertically with reference to the outer frame;

5 a workpiece mounting platform, carried by said inner frame, and being controllably moveable by one or more actuators horizontally with reference to the outer frame; and

control circuitry, connected with said anchoring devices, said actuators and said proximity sensors, to control said anchoring devices' movement, and to control movement of said inner frame and said mounting platform such that a workpiece may be sited at one or more desired locations, or over a path, on said surface.

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Brief Description of the Drawings

Embodiments of the invention will now be described with reference to the accompanying drawings, in which:

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Figure 1 shows the servicing apparatus in use with reference to a building exterior;

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Figure 2 is a perspective view of the servicing apparatus's gondola;

Figure 3 is schematic diagram showing details of a linear actuator;

Figure 4 is a schematic view showing details of a gear and motor assembly;

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Figure 5 is schematic diagram showing details of one of the anchoring devices;

Figure 6 is a schematic diagram showing a drive mechanism for the workpiece mounting mechanism;

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Figure 7 is a schematic view of a workpiece in the form of a cleaning brush;

Figures 8A – 8D show operation of the workpiece on an uneven wall surface; and

5 Figures 9A – 9E show similar operational arrangements to Figs 8A – 8D, except for a different direction of travel.

Detailed Description and Best Mode

10 The invention may be practiced in relation to the outer walls or sides of high-rise buildings, which is the embodiment that will presently be described. The invention also may be practiced in performing work operations on external surfaces of oil rigs, in slipways for vessel maintenance, and down the interior of chutes. The invention is most usually practiced in an unmanned mode, and under remote or automated control.

15 The work operations that can be performed include washing, spraying, abraiding, painting, polishing, welding, and inspection, amongst others.

20 Throughout this specification a particular cartesian coordinate referencing system has been adopted. The reference axes are shown on the accompanying drawings (adopting a “x, y, z” nomenclature).

25 Referring now to Figure 1, a portion of the external surface of a high rise building 10 is shown. The building’s façade typically will be constructed of materials such as glass, plastics or sheet metal. The exterior surfaces of the buildings walls are shown to be smooth, however as will be demonstrated, a particular advantage of the invention is its ability to perform desired servicing operations on surfaces that are irregularly shaped.

A form of track 12 is sited on the roof of building 10, and carries a motorised support platform 14. The platform 14 has mounted from it a pair of guides 16 that support respective wire cables 18 by which a gondola 20 is suspended. Trailing cables or conduits 22 span between the gondola 20 and an equipment housing 24 also carried
5 on the support platform 14.

In broad terms, the gondola 20 is moved laterally of the building (i.e. in the x direction) then raised or lowered on the cables 18 to arrive in the vicinity of the work site. If the servicing operation is cleaning, then the gondola 20 will typically follow a
10 pattern of movement to cover the entire surface in a piecewise manner.

Referring now to Figure 2, a detailed schematic view of the gondola 20 is shown. An outer frame (or cage) 30 provides the basic superstructure, which is supported from the cables 18 by geared climber motors 32, that are themselves fixed to the outer cage
15 30. Alternatively, the prime mover could be located on the support platform 14 at the roof level. Extending away from the outer cage 30, and located at the four corners thereof, are anchoring devices 33 in the form of suction caps 34 carried on a linear actuators 36. The actuators 36 operate to extend the respective suction cups 34 towards
20 the surface upon which the servicing operation is to be performed. In the context of the present embodiment, this is the surface of a wall of the building 10, as shown in Figure 1.

The gondola 20 further includes an inner 'H' frame 38, constituted by two vertical members 40 and a horizontal member 42. The vertical members 40 engage
25 actuators that are lying within the hollow "z" members 44 of the outer cage 30.

A workpiece mounting platform 46 is mounted from the horizontal member of 42, and its operation will presently be described.

On both sides of gondola 20 are provided enclosures 48 that house electrical switchgear and controlling logic. Additionally, a compressor pump 50 may be sited on a platform on the top of the gondola 20, together with a service container 52, in which the trailing cables and/or conduits 22 are terminated.

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The workpiece mounting platform 46 carries a drive mechanism 54 providing three degrees of freedom. Workpieces or tools (not shown) are mounted from the drive mechanism 54, as will be presently described.

10 Figure 3 shows greater details of an embedded linear actuator 58 within the z members 44 of the outer cage 30. The end portion 60 of the member 40 is received in a slot 62 and guided in the slot by a guide bar 64. The two vertical members 40 thus can be controllably moved within the slot 62 (in the z direction) by engaging a ball screw 66 that is driven by a motor 68. There are either two or four such linear actuators 58
15 located in two or each of the z members 44 forming a part of the outer cage 30. The two (or four) drive motors 68 thus must be controlled in synchronism so as to move the inner frame 38 'forward' and 'backward' along the z-axis with precision.

Figure 4 shows details of the actuators included in the inner frame 38, namely
20 two and the linear actuators 58 carried within the vertical members 40 and one linear actuator 58 within the horizontal member 42. Each of these members 40, 42 carries a motor 68 and ball screw 66 that are respectively controllable such that the horizontal member 42 can be moved 'up' and 'down' in the directions along the y-axis and the workpiece mounting platform 46 can be controlled to move in 'left' and 'right'
25 directions along the x-axis.

By the arrangement shown, particularly in Figures 3 and 4, it is possible to locate the workpiece mounting platform 46 at the desired location with full x-y-z directional control.

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Figure 5 shows greater detail of one anchoring device 33 formed by a linear actuator 36 and distal suction cup arrangement 34. The linear actuator 36 operates to extend or retract a shaft 70, the end of which carries the suction cup 34. The ball screw 68, connecting with the shaft 70, is under control of a motor 68. By appropriately controlling the motor 68, a desired degree of extension of the shaft 70 can be obtained. In operation this is for the purpose of moving the suction cup 34 to engage with the surface upon which the work is to be done. The suction cup's operation is given effect by a vacuum chamber 72 lying behind it, that has communication with the suction cup's interior. The vacuum from a pump (not shown) is provided by an appropriate conduit 74. The suction cup 34 also includes a force or limit-switch sensor 76 which operates to provide a controlling feedback electrical signal at the point of engagement of the suction cup 34 with the relevant surface.

Figure 6 shows further details of the drive mechanism 54 mounted from the workpiece mounting platform 46. Only abbreviated details have been shown for the sake of clarity. A motor 80 drives a ball screw 82 providing for travel of the base 84 in the z direction within the limits of the slot 86. Another motor 88 and corresponding ball screw (not shown) provides for rotational motion about the y-axis. In similar way, a yet further motor 90 and ball screw (not shown) provides for rotational motion about the x-axis. The workpiece for the servicing operation to be performed is mounted from the top plate 92 of the drive mechanism 54.

Figure 7 shows the example of one such tool, being for a cleaning operation. A housing 100, which affixed to the top plate 92 of the drive mechanism 94, contains a linear motion actuator in the form of a motor 102 and ball screw 104. The cleaning head 106 is carried on a shaft 108 which forms part of a rotary motion motor. In this way the brush 110 rotates within the housing 112 of the cleaning head 106. Water and detergent are provided by a channel 114 into the open space between the edge of the housing 112 and the outer circumference of the brush 110. Into the same space passes a

vacuum line 116, which serves to remove water and detergent, thus avoiding leakage of such liquids.

It is now useful to discuss the full operation of the apparatus referring again to Figures 1 and 2. Depending upon the work operation to be performed, an appropriate workpiece is mounted from the drive mechanism 54 and the gondola 20 is positioned to be in the approximate work location adjacent to the surface (in this case the building façade). Next, the anchoring devices 33 are operated. The four linear actuators 36 extend the respective suction cups 34 towards the surface, and are controlled to stop when contact is made, as determined by the force or end-travel (i.e. proximity sensors 76). These anchoring devices operate independently, meaning that the gondola 20 can still be effectively anchored in an appropriate orientation to perform the work even for an uneven or irregular surface.

Once the gondola 20 is anchored to the general work area surface, the workpiece can be precisely located by y-axis and z-axis motion of the inner frame 38, and x-axis motion of the mounting platform 46. Once the workpiece has been sited, the work operation can commence. Precise motion of the workpiece can be achieved by the x- y- and z-axis capabilities of the workpiece drive mechanism 54. This allows the workpiece to manoeuvre over uneven surfaces.

Of course, the area in which work is to be done can be over the full extent of travel of the inner "H" frame 38 and the workpiece mounting platform 46, and such motion can be pre-programmed or controlled remotely. For the purpose of such remote control, one or more cameras might be permanently mounted from the outer cage 30 to get a wide angle view and on the workpiece mounting platform 46 to get a close-up view of the work operation. Typically pre-programmed serving work can be performed where the full extent of x and y motion is undertaken, whilst remote control may be more suited to localised operation. In the case of automated control, a programmable logic controller, or the like, must be provided.

Figures 8A – 8D show a top view of a brushing operation where the building surface is irregular. The respective linear actuators 36 are extended to different degrees because of the irregularity in shape, however, the outer cage 30 remains in a position appropriate for stably conducting the operation. In Figure 8A, z-axis control is achieved by the inner frame 38 moving with reference to the z member 44 such that the brush 120 contacts the surface to perform the operation. As shown in Figure 8B, the workpiece mounting platform 46 has not moved in the x direction, rather the drive mechanism 54 (i.e. motor 88) has rotated so that contact is maintained on the next portion of the surface being operated upon.

Figure 8C shows that the workpiece mounting platform 46 has been moved in the x direction and the drive mechanism 54 has rotated back to its original position so that the brush 120 is now again effectively performing its operation. Figure 8D shows the opposite adjustment to that shown in Figure 8B.

Referring now to Figures 9A – 9E, these represent side views of the gondola 20 attached to an uneven wall surface and performing an operation extending in the y direction over that surface. Again, the linear actuators 36 are extended to a different extend to cope with the uneven surface. As the horizontal member 42 traverses in the y direction there is appropriate control over the drive mechanism 54 in rotation (i.e. motor 90) to maintain the brush 120 in its correct operational orientation in respect to the surface.

The foregoing embodiment describes a cleaning operation. The fluids for this operation will be stored in the service container 52, which may have a sufficient capacity to perform the operation, else the container can serve as a reservoir that is replenished by supply from the roof by a trailing conduit 22. The fluids are able to be pressurised by the compressor pump 50, as need be.

Other forms of workpiece will be apparent to those skilled in the art.

The materials from which the gondola 20 and associated components may be constructed will also be readily apparent to those skilled in the art. Aluminum tubing is
5 one such suitable material.

Whilst motorised ball screw actuators have been described, other forms of actuator may also be used, including worm, belt driven, or rack and pinion gearing.

10 Numerous alterations and modifications, apparent to one skilled in the art, may be made without departing from the spirit and scope of the invention.

**CLAIMS:**

1. Apparatus for use in the servicing of an exterior surface of a structure, comprising:

5 a rectilinear outer frame adapted to be suspended from a supporting structure and raisable and lowerable by hoisting means;

anchoring devices located at or near the corners of one face of said outer frame, and extending away therefrom, said anchoring devices being independently operable to extend laterally towards the surface to be serviced, and having sensors therewith to
10 sense proximity of said surface;

an inner frame mounted from said outer frame in a manner to be controllably moveable by one or more actuators laterally of the outer frame, said inner frame also being controllably moveable by one or more actuators vertically with reference to the outer frame;

15 a workpiece mounting platform, carried by said inner frame, and being controllably moveable by one or more actuators horizontally with reference to the outer frame; and

control circuitry, connected with said anchoring devices, said actuators and said proximity sensors, to control said anchoring devices' movement, and to control
20 movement of said inner frame and said mounting platform such that a workpiece may be sited at one or more desired locations, or over a path, on said surface and caused to operate.

2. Apparatus as claimed in claim 1, further comprising a drive mechanism mounted
25 from said mounting platform, and having actuators, under control of the control circuitry, adapted to move a workpiece in translation laterally with respect to the outer frame and in two orthogonal directions of rotation.



3. Apparatus as claimed in claim 1 or claim 2, wherein said actuators comprise motorised ball screw gears that are seated within respective frame members and engage ends of co-operating members to cause relative motion.
- 5 4. Apparatus as claimed in claim 2 or claim 3, further comprising a workpiece, mounted from said mounting platforms and under control of said control circuitry, chosen from at least a rotating brush, a spray nozzle, a rotating abraiding tool and a welding tip.
- 10 5. Apparatus as claimed in claim 4, wherein said workpiece further comprises an actuator to allow controllable lateral movement.
6. Apparatus as claimed in any one of the preceding claims, wherein said control circuitry is programmed to site and operate said workpiece in accordance with a desired servicing operation, or is subject to remote control signals to perform said desired servicing operation.
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