Automation in Action

Options for Autonomous Surface Preparation and Coating Application

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Throughout the world, automation across most industries has been increasing for decades. This article will examine some of the ways in which automation is being designed and used to improve surface preparation, coating and inspection processes. It will begin with examining the design parameters that affect the usefulness of each type, including the strengths and weaknesses for each. Subsequently, several examples of currently employed technologies will be highlighted, including on ship hulls, aboveground storage tanks and other industrial applications.

ROBOT DESIGN CONSIDERATIONS

A robot must be designed to carry a payload to a location where it can perform a task. For surface preparation and coatings application, some of the more common payloads include cameras, inspection instruments, surface preparation devices and paint guns. There are several variables in robotic design that can be tailored to specific applications and/or payloads. To illustrate the breadth of options and functionality, the following is a review of mobility and adhesion system designs, as well as levels of autonomy and programmability.

Mobility System Design

The overall design of a robot's chassis and mobility system has a significant influence on the robot's capabilities. There are several different designs, each with advantages and disadvantages for use as a surface preparation and coating robot. Wheeled vehicles, tracked vehicles, double-frame motion, rail-based motion, human-assisted motion and fixed pivot point with a mobile arm have all been used successfully.

One of the most popular mobility designs is wheeled vehicles. A significant advantage of this design is its simplicity and continuous motion due to the rolling mechanism. However, a drawback is that the wheels could get stuck on large objects.

Tracked vehicles are like wheeled vehicles in that they use a rolling motion to move the robot. The track design allows for the robot to surmount larger objects. Tracks or treads also make more surface contact than wheels, giving them more grip (less slip). For magnetic adhesion, this increased contact area also reduces the likelihood that the robot will fall.

On steel surfaces, the double-frame design utilizes the motion of walking instead of rolling. Two frames are connected to each other in such a way that they can move (translate and/or rotate) relative to each other. Two sets of four magnetic feet are used. During the "walking" motion, one set of magnets will demagnetize, allowing four of the feet to be lifted from the surface and moved along linear actuators. This permits the vehicle to "walk" and turn. The feet are also on ball and socket joints, so they can maximize contact with the surface the robot is walking on. The demagnetization of the feet also helps avoid a large amount of steel particles sticking to them in an abrasive blasting application. However, this design comes with some disadvantages. A double-frame robot's motion is largely discontinuous, resulting in slower production rates than alternatives. These designs can also be relatively sizable and might not overcome obstacles as well as the other mobility designs.

A rail-based robot makes use of a pre-existing rail system to travel through an area. The advantage of this system is that there is a high degree of control and programmability, thus enabling faster travel than other methods. Barring any damage to the rail or blockages along the path, the location of the robot is easy to determine since its motion is limited. An extendable arm attached to the robot adds more degrees of freedom and allows the robot to access more areas and varied surfaces on complex structures.

An example of a rail-based design is a robot created for inspection and maintenance inside of ballast water tanks on ships. This robot was created to automate the process and remove the need for human entry into the tanks and eliminate the associated confined space entry requirements. However, one major drawback of the rail-based system is that a rail must be built and installed in the working area before the robot can operate. Until proven, this can be a costly and potentially risky investment. On the other hand, if successfully installed, this is a one-time investment that can reduce future maintenance costs.

Some robot designs do not move themselves around at all. While they may have an arm that can rotate and extend outward from the fixed base, the robot itself remains stationary. Such designs have various methods of interacting with a part – the robot can move around the part (via a robotic arm), the part can be moved and rotated under the robot, or there can be a hybrid of the two methods.

An example of a robot moving around a part are robotic arms designed for painting components. Multiple articulation points allow the arm to reach and paint all areas of the object. The arm is mountable on floor, wall, or ceiling—providing opportunity to accomplish a variety of painting tasks. This design is typical of fixed robots with similar capabilities.

Fixed robots can also complete tasks without a significant amount of motion if the part is moved around the robot. For example, a component could be placed on a motor that rotates during the painting process, limiting the motion needed for the paint gun. This style of design could be used on a method of construction through which parts move or rotate under robotic arms, such as assembly line conveyors.

Adhesion Design

For robots that must climb to complete their task, the method of adhesion is a very significant design decision. Any failure of the adhesion method will result in the robot falling from the operating height, likely breaking equipment or sensors on impact. With the specialized technology and devices required for robots of this type, such damage can prove quite costly, and time for repairs will further take away from productivity.

Fig. 1: Automated surface preparation units can be attached to ships' hulls for coating removal. *Photo: Courtesy of Blastone International*

A climbing robot used in the shipbuilding process will most likely be traversing a steel surface. Robotic adhesion can be achieved by suction force, magnetism, mechanical attachment, and chemical adhesion. The different adhesion designs are discussed in this section.

Magnetism is a popular adhesion design that makes use of magnetic attraction between material in the robots' wheels, tracks, or legs and the surface on which the robot is operating. This can be accomplished by using permanent magnets or electromagnets. The design provides a very strong adhesion force that can bear a large amount of weight, but it can only be used on ferromagnetic surfaces.

Fig. 2: This magnetically attached crawling unit performs grit-blasting on a ship's hull. *Photos: Courtesy of Blastone International*

Adhesion by suction allows for operation on essentially any surface that is smooth and free of cracks. The major disadvantage of suction is that excessive flaws in the surface or gaps in the seal will cause the suction to fail. Surface preparation robots can use a vacuum to create a suction force strong enough to maintain adhesion to the operating surface while also removing surface preparation debris. This is common for waterjetting systems.

Some robots use features such as leverage to hold themselves in place upon the operating surface. These robots have claw-like legs or gripping equipment that grab protrusions from the surface. For example, an autonomous blast-cleaning robot has been designed to crawl along longitudinal stiffeners inside a ship. The limit of this style of adhesion design is that there must be features for the robot to grab.

Chemical adhesion involves the use of a sticky material attached to the contact points of the robot (e.g. glue). While it can provide a strong initial adhesive force, as it is used multiple times the effectiveness of adhesion decreases rapidly in situations that have dust or other particles present. Accordingly, chemical adhesion is not typically chosen for use on mobile robots.

Degree Of Autonomy

Many manual tasks take up time and manpower. Automation can minimize cost of labor and allow workers to focus on tasks that cannot be automated. However, there is a spectrum of automation between manual labor and the full-scale automation of a task.

Remote control of a robot or machine is the first step into the automation spectrum. This allows an operator to watch and directly operate the machine from outside the operating area. Such a function is particularly useful in environments that could endanger the worker's life or health if they were manually accomplishing the task. For example, a remote-controlled waterjetting robot can operate while climbing vertical surfaces with magnetic treads. Though a person is directly controlling it, the robot can access and prepare the surface faster than a normal worker. While there is still an operator controlling the robot, a consistent standoff distance is maintained, saving time during the task while also making it safer.

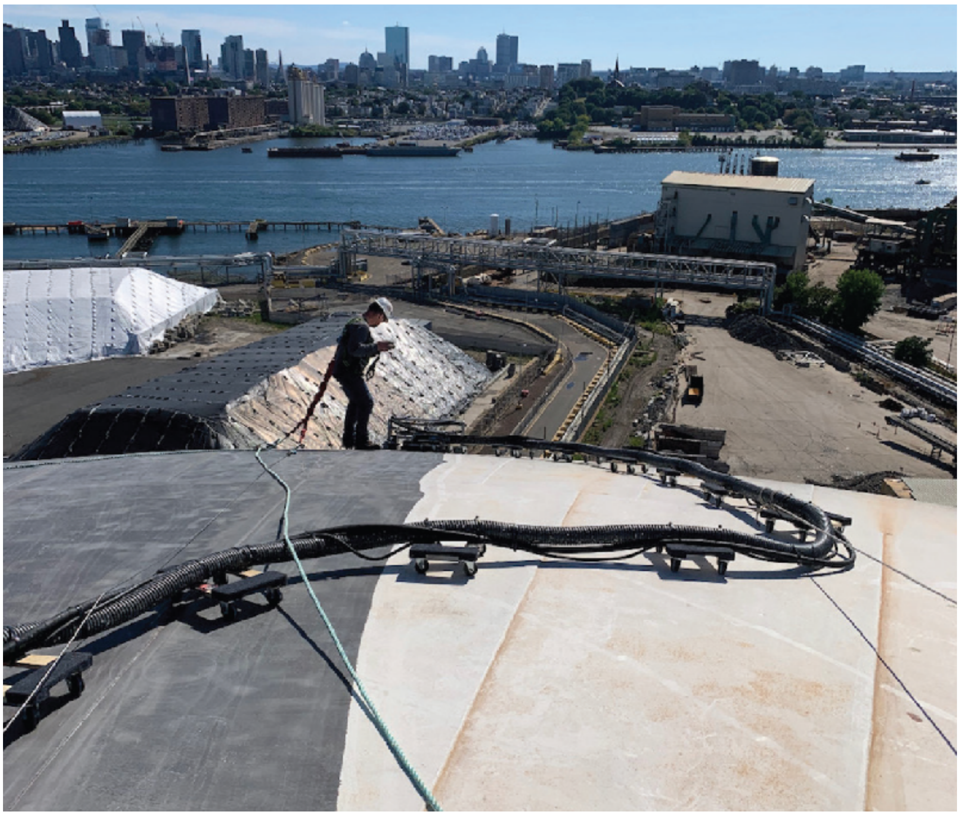

Fig. 3: Automated units can be employed on large structures such as bridges and storage tanks. *Photo: Courtesy of Allstream Services & Rentals, LLC*

Semi-autonomous operation of robots can encompass many different combinations of control. For example, the aforementioned remote-control waterjetting robot would be semi-autonomous if it automatically proceeded in a straight line at a consistent rate before reaching some identified end at which point it shifted and reversed direction, cleaning a swath of work surface adjacent to the one it just cleaned.

At the end of the spectrum is full automation of a process from beginning to end. This may require integration and/or adaptation of other pre-existing automated material-handling equipment to ensure a continuous process. For example, the waterjetting robot described earlier would be fully automated if it could clean an entire work surface (e.g., exterior tank surfaces) without human interference.

Fig. 4: Automated crawling surface prep equipment can allow coating application to follow in its path. *Photo: Courtesy of Allstream Services & Rentals, LLC*

Programmability

Another design factor to consider while building a robot suited for a specific task is how easily the task can be programmed. Tasks that are repetitive in nature are usually more easily programmed, while complicated tasks that depend on multiple or varying factors might not lend themselves to full automation.

An automated surface preparation and painting robot built for use within the compartments of ships will require programming of many processes and its operation depends on many factors. Some things to consider are its motion through the compartment, motion of a robotic arm (if applicable), how long blasting/coating must occur for a given area, how to tell if an area needs more treatment, obstacle avoidance, and sensors to recognize abnormalities on the surface. Some of those factors have been considered and programmed successfully in other projects, while others might not yet be completely developed.

Fig. 5: Large robotic units can be used for thermal spray application, including the interior of pipes. *Photo: Courtesy of Blastone International*

CURRENT INDUSTRIAL TECHNOLOGY

There are several existing robotics and automation technologies that are used in surface preparation, coating, and inspection processes. Some of these systems were described in a January 2021 JPCL article; similar systems, as well as other automated options, will be discussed in the following paragraphs.

Commercially available high-speed, semi-automated robots perform ultra-high pressure waterjetting (UHP WJ) on underwater hull and freeboard surfaces. The semi-automated surface preparation can be adjusted to remove all coating or only loose or delaminated coating. UHP WJ may use magnetic wheels or vacuum to remain in close contact with a surface, though cables support the equipment for safety. Integral vacuum systems collect water, removed paint and corrosion products/debris. The unit operator maneuvers the robot across surfaces using a wireless or wired controller.

Aerial inspection drone technology has been developed that can provide measurements for either dry film thickness or wall thickness. The current technology requires clear weather conditions with winds below 15 knots. The system allows for 360 wall thickness readings or 1,000 DFT readings per hour. Depending on wind speed, the onboard battery allows for flight times of 10–20 minutes, with the ability to work with a tether and ground power. Technology for coatings application is also under development.

Robotic technology has also been developed to be deployed for projects involving bridges, tanks, marine structures, confined spaces, blast rooms, and hazardous areas. One presently available system uses a robotic arm that can scan the area to locate obstacles and irregularities in the surface. Once scanning is complete, software plans a path for abrasive blasting, takes into consideration necessary obstacle avoidance, and begins blasting the area. The system has been proven to function in various environments and is presently used in over 30 tanks or vessels worldwide.

A DC-powered wireless remote-controlled crawling robot has been specifically designed for surface preparation over steel substrates. The frame is constructed with aluminum, the chain drive is made of steel, and all other hardware is constructed with stainless steel. Urethane treaded wheels are used for mobility. The unit uses magnets assisted by vacuum to traverse walls and sloped surfaces. The robot is completely self-contained; all removed coating, rust, water, and contaminants are sent through a filtration system for disposal. The robot produces no air contamination and complies with all environmental regulations.

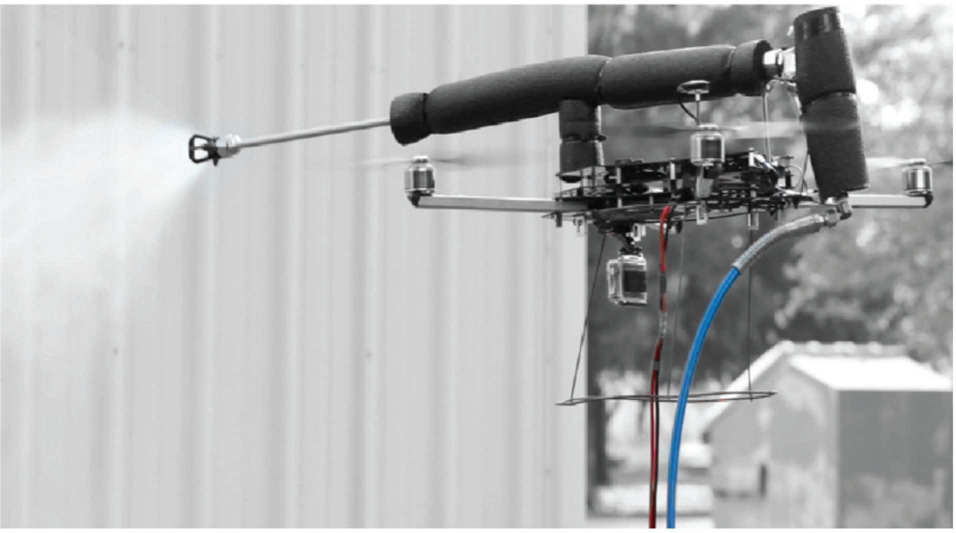

Fig. 6: A remote-controlled spray coating application drone is currently under development. *Photo: Courtesy of Apellix*

One semi-autonomous robot has been developed that executes abrasive blasting of ship exterior hulls. The vehicle is a commercial high-reach with a set of abrasive blasting nozzles attached to the end of the equipment. Once the arm of the robot is positioned, the robot automatically follows the ship contour and conducts the abrasive blasting. Dust, paint, and grit are collected through a vacuum system and sent to a recycling unit, where the abrasive grit is recycled with a reported 95% efficiency.

Another design that can be used for inspection purposes involves a walking robotic unit. This type of unit is a commercial-ready platform which is designed to perform tasks either autonomously or with human input. It can last approximately 90 minutes on a charge and can navigate 36-cm-height obstructions and traverse uneven terrains. The unit can be equipped with a camera module which provides a color panoramic view of the robot's surroundings for inspections. The unit currently lacks an edge detection system and requires a signal back to the controller or home station to operate.

A commercially available robot is available for high production thermal spraying. Automated capabilities improve coating consistency, reduce operator safety hazards, and can reduce installed cost. This system rasters multiple thermal spray across a surface with little operator interaction until the operating footprint is properly coated. Similar systems have been designed for coating pipe. Once the robot is in place, the pipe is automatically rotated and translated below metalizing equipment until the task is complete.

Existing technology has also been designed for use as a semi-autonomous crawling unit to traverse the interior of large diameter pipes with surface preparation and painting capabilities. The systems function through semi-autonomous manipulation of the blast nozzles while crawling down the pipe.

CONCLUSIONS

There are several examples of presently available automation and robotics for surface preparation and painting activities that can generally be classified into the following groups:

- Industries having the advantage of simpler shapes (e.g., onshore product storage tanks, barges, or railcars) or well-suited production lines (e.g., automobile manufacturing, commercial item manufacturing); and
- Abrasive blasting and primer application of simple shapes (e.g., "plate lines") and cleaning and coating small parts (e.g., pretreatment and power coating lines).

Obstacles to increased automation of surface preparation and coating activities include cost, culture and commitment of management, and supporting infrastructure (e.g., IT systems, workforce). However, the largest gap may be the complex, integrated nature of most coated surfaces and the need for expanded sensing and mobility to allow for increased autonomy and obstacle negotiation.

Three paths exist for increased automation of surface preparation and coatings activities.

- Incrementally improve existing processes through automation of individual steps such as material handling or inspection/recordkeeping.
- Broader use of proven technologies such as automated abrasive blasting, waterjet robotics, and automated laser depainting. With a tailored business case, the technologies could be readily adopted and incorporated beyond existing uses, ultimately enabling an automated future in a wide variety of applications.
- Transformational opportunities will depend on the development of designs that are more conducive to automation (e.g., repetitive or robot-accessible designs) or the development of automation-friendly materials and processes (e.g., coating materials which can be applied using electrostatic equipment).

References

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