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Autonomous Mobile Robots For Deep And Shallow Hydrodynamic Treatment Of Concrete And Metal Surfaces

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ABSTRACT

The paper presents characteristics of a mobile robot for hydrodynamic treatment of concrete and metal surfaces. The robot is moving on two tracks with a robot arm able to carry various water jet tools. The size of a robot allows easy transportation and manoeuvring in very confined spaces. Besides two tracks, the on-board system controls also a beam, a rotor tool, lance swing and pitch angles, and a tool-to-surface distance deviation. During operation, a tool is automatically adjusted towards a treated surface. Addition of a vacuum unit allows suction and storage of all water and material during treatment. Robot tests in real exploitation conditions have confirmed all advantages of the described robot design for possible water-based decontamination of metal and concrete surfaces in nuclear power plants.

1 INTRODUCTION

Vital parts of nuclear power plants (NPP) are mainly built of steel and concrete. In order to prevent major disasters and damages, the inspection and maintenance of critical places plays a crucial role in extension of NPP's lifetime. Despite all taken measures, massive natural disasters, like the one that happened recently in Tepco NPP, Fukushima, Japan, can cause irreparable damages which must be repaired anyhow. The sections of the plant being contaminated are main candidates for introduction of robot-based decontamination.

Decontamination of a human body using water (washing) is a standard method used in medical practice. Water flushes and absorbs radioactive materials and as a consequence, becomes contaminated itself. Therefore, the water being used must be collected and stored for later decontamination. There is a straight congruence between the medical decontamination and the possible use of robots for the same purpose.

Very often, treatment of damaged concrete and steel structures is performed by using robots equipped with high-pressure water jet tools [1-3]. This has been found very effective in case of automated cleaning, profiling, removal, drilling and demolition of concrete substrates and reinforced concrete structures [4]. A high water pressure needed for robot's operation is provided by the accompanying filtering and pumping unit. The result of applied treatment is a clean surface, but a large amount of removed material and water must be collected and stored without leftovers. In case of robotic decontamination, a system needs a suitable vacuum suction and storage unit. A lightweight hydrodemolition mobile robot described in [5] has all characteristics needed for upgrade to an autonomous or teleoperated decontamination robot.

The paper is organized as follows. A modular robot design is described in Section 2. An overview of control functions of the implemented robot control system is presented in Section 3. Comments on robot's applicability to decontamination jobs in nuclear power plants are presented in Section 4. We conclude the paper with an overall assessment of robot characteristics.

2 TECHNICAL DESCRIPTION

Robots shown in Figure 1 are lightweight, mobile robots equipped with Advanced Guiding Systems – AGS and wireless remote control, which execute deep and shallow high pressure water treatment (1000 – 3000 bar) of concrete and metal surfaces. Such applications are often seen in the construction industry for hydrodemolition and decontamination purposes.

Figure 1: Modular construction of R Jet 06 hydrodemolition robots

R Jet Robots are controlled remotely with a possibility of using external video system to enable the setting up of the robot for operations where human operators are not allowed either because of inaccessibility or hazardous environment. Advanced Guiding Systems enable robots to work autonomously without constant input from the operator making them automated in completing on-site jobs. Currently there are different AGS depending on the job requirements enabling automated treatment of walls, floors and ceilings (from 0,8 – 4 m height), cylindrical surfaces and pipelines (0,9 – 4 m diameter), as shown in Figure 2.

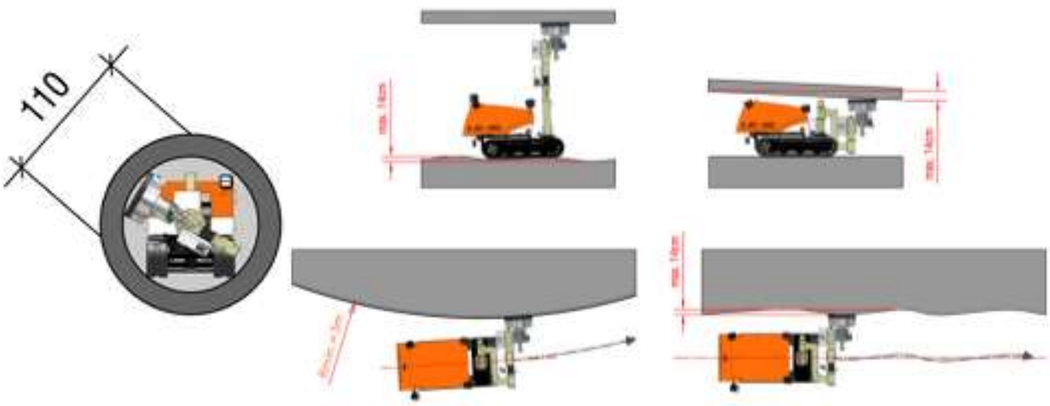

Figure 2: Decontamination tasks – pipes, ceiling, floor, wall following

3 ROBOT CONTROL

Robot control has been implemented by using state-of-the-art servo control equipment which supports Ethernet and Open CAN communication standards. Due to harsh conditions in which the robot operates, a WLAN remote control console shown in Figure 3 enables the operator to operate the robot from a safe distance without a direct visual contact with the robot and drive the robot in the initial working position.

Once being there, the robot can continue its operation in a fully autonomous way. For example, it can execute continuous step by step passing over a surface, wall following and straightforward robot motion, rotation of a robot link carrying a robot tool (e.g. during the treatment of a pipeline wall) and other tasks which may be required during a preplanned or on-site defined decontamination patterns.

Figure 3. Remote control console for operating a robot from safe distance.

Efficacy and leveled quality of decontamination largely depends on:

- The equidistant guidance of a robot tool over a treated surface by controlling the correction axis,
- Control of a rotor tool rotation,
- Lance swinging control that enables linear motion of water jet tool over the surface (in combination with tracks control),
- Control of a lance pitch angle under which the lance tool attacks the surface.

As shown in Figure 4 originally presented in [5], the robot is equipped with an inertial navigation system (INS), encoders and ultrasound sensors that enable the implementation of track control algorithms. An inertial navigation system contains a set of sensors (i.e. accelerometers and a gyroscope) and calculates the orientation and the velocity of the robot. By combining the INS with encoders and ultrasound sensors, straight forward motion and wall following algorithms have been devised. The track ultrasound sensors (1) help ultrasound sensors (4) to control the desired tool distance from the treated wall (5).

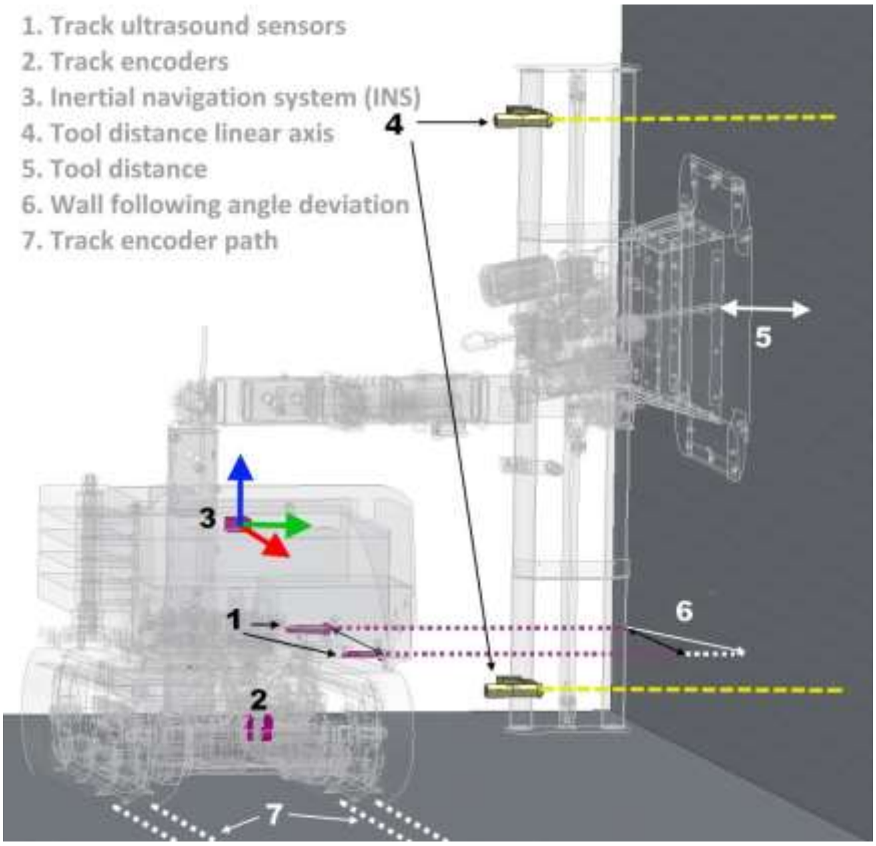

Figure 4: Control system and sensors applied to a wall treatment example [5].

Combined with the wall following algorithms, a linear correction axis assures that a desired tool distance from a treated wall is kept constant. For this purpose, an interpolation-based algorithm for automatic adjustment of robot tool distance is executed. The linear correction axis and track control work independently, but in some applications, the wall following algorithm can be used to compensate deviations from the treated surface, and in such occasion the two algorithms are used concurrently.

4 APPLICABILITY TO NUCLEAR POWER PLANTS

A very unique characteristic of the presented hydrodemolition robots is that they are fully electrically driven robots characterized by low energy consumption. Their size allows them to operate in different sections/buildings of nuclear power plants as they can easily pass through standard doors and climb the stairs.

The robots have been designed as a multipurpose modular platform enabling them to accept different types of tools or to be dismantled in matter of minutes and carried in less accessible areas. This becomes very advantageous when different decontamination jobs are carried out and when a robot itself must be decontaminated. In order to enable water jetting in water free environment, robots come equipped with a 20 nozzle rotor tool with a vacuum ready unit that can be attached to any compatible suction system.

The performance of the R Jet 06 robots was proved to be effective on several hydrodemolition tasks executed involving treatments of floor and wall concrete surfaces, as well as paint removal, using a vacuum ready unit for removing all water and treated material during decontamination. In Figures 5 and 6 one can see that the results of applied treatments were very satisfactory, with almost 99.99% of all water and treated material successfully removed and stored in safe containers.

Figure 5. Hydrodynamic treatment applied to the concrete floor surface.

Figure 6. Hydrodynamic paint removal treatment applied to the concrete wall surface.

5 CONCLUSIONS

R Jet Robots have characteristics suitable for collection of contaminated surface deposits, removal of contaminated epoxy coatings or for deep and surface decontamination of contaminated concrete.

Due to their AGS and wireless control the robots fulfil basic requirements to be used for high pressure water jetting or operation with other decontamination media, if one of these technologies would be used in the damaged nuclear power plants. Advanced guiding systems should simplify remote decontamination, as constant input from operators would not be necessary. Robots can be operated on rough and uneven terrains and thanks to their compact and lightweight design they could fit in tight spaces and enable decontamination of these areas. A vacuum ready unit should enable storage of contaminated water and ensure water free environment.

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REFERENCES

[1] T.J. Labus, Material excavation using rotating water jets, Proc. 7th Int. Symp. Jet Cutting Technol. (eds. I.A. Walls, J.E. Stanbury), BHRA, Cranfield, 1984, pp. 503-518.

[2] F. Hammelmann, Directional hydraulic pulse blasting, Water Jet Applications in Construction Engineering (ed. A.W. Momber), A.A. Balkema, Rotterdam1998, pp.91-103.

[3] D.A. Chamberlain and E. Gambao, A robotic system for concrete repair preparation, IEEE Robotics & Automation Magazine, Volume 9, Issue 1, Mar 2002, pp. 36-44.

[4] A. Momber, Hydrodemolition of concrete surfaces and reinforced concrete, Elsevier, 2005.

[5] Kovacic, Z.; Balac, B.; Flegaric, S.; Brkic, K.; Orsag, M. Light-weight Mobile Robot for Hydrodynamic Treatment of Concrete and Metal Surfaces“, The 1st International Conference on Applied Robotics for the Power Industry CARPI 2010, Montreal, Canada, 2010.