

MANIPULATOR-DEPLOYED SYSTEMS FOR SURFACE DECONTAMINATION IN NUCLEAR FACILITIES

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Abstract: Due to the phasing out of nuclear energy in Germany there are a growing number of nuclear facilities that have to be decommissioned within the next years. In this context a multitude of surfaces in nuclear facilities have to be decontaminated. Manipulator-deployed systems offer a suitable solution and are properly designed for this kind of task. Beyond that they can be used for the processing of surfaces in civil as well as industrial fields of application, e.g. the stripping of coatings on metal surfaces. By the use of a suitable supporting system various attachments like a milling machine or laser can be carried and operated on walls and ceilings. Vacuum suction plates guarantee the interconnection between the supporting system and the object to be treated. Due to the intricate processes as well as the required flexibility arising from the multi purpose use with milling or laser attachments a robust control system with a high performance and a high level of customization is required. The following article introduces to you the systems in detail.

1 INTRODUCTION

Due to the phasing out of nuclear energy in Germany there are a growing number of nuclear facilities that have to be decommissioned within the next years. In order to successfully dismantle and decommission these facilities a great amount and variety of processes and actions is required.

Among other things these include the qualified decontamination of surfaces. The associated tasks are manifold, ranging from simple cleaning to complete surface ablation. The latter is particularly challenging due to the multitude of surfaces in nuclear facilities that have to be decontaminated.

In this regard, effectiveness and economic efficiency play an important role as well as the avoidance of secondary waste and cross contamination (Gentes, 2006: 416, 417). Therefore the selection of an appropriate process and system is crucial.

But only a few of the currently available processes for the decontamination of surfaces fully meet the required criteria and are applicable for this kind of task. Therefore the nuclear industry calls for more suitable and efficient decommissioning technologies.

The Institute of Technology and Management for the Decommissioning of Nuclear Facilities at the Karlsruhe Institute of Technology (KIT) has addressed itself to this task and thus is conducting research as well as is developing innovative processes and machines for this kind of purpose. All this is done in co-operation with industry partners that are focused on carrying out decommissioning activities in the field. This kind of co-operation helps to generate feedback in order to improve the machines.

2 THE BASIC IDEA

The decontamination of surfaces in nuclear facilities is an intricate and time consuming process. It is very labour intensive, because most techniques are hand-operated or difficult to handle by just one person. Compared to the output of a machine the performance of labour is very low. Thus more labour is required in order to be cost-effective.

Furthermore the timeframe for works conducted in the hot zone, which is the controlled area inside of a nuclear facility, is very limited per worker and

shift (HVBG, 2004: app. 2), due to the required use of breathing apparatuses. Because of that several teams have to be employed on alternating shifts to ensure a proper exchange of labour which finally results in a better practical performance.

Another important aspect is the high effort that comes along with many of the techniques being used for the decontamination of surfaces. In numerous cases scaffolding is needed, especially in rooms with big ceiling heights. Besides that extra time is required for the set-up of equipment or machinery. But the time spent on works preparation reduces the overall period available for decontamination. Thus it makes even suitable techniques less effective.

Based on these facts the idea was born to construct and build a manipulator that is able to climb on walls and ceilings autonomously, in order to decontaminate surfaces by means of a milling attachment or laser. The manipulator requires no scaffolding or elaborate set-up. Besides that there is only one operator needed to run the machine. Finally the use of a manipulator results in a greater economic efficiency.

3 MACHINE SPECIFICATIONS

Several requirements have to be met for the successful decontamination of surfaces in nuclear facilities. Besides the requirements requested by the clients, e.g. regarding safety and economic efficiency of the particular technique, there are requirements that originate from the structural conditions of a nuclear facility.

The relevant criteria have to be taken into account when setting up a manipulator system. Hence the following specifications have to be implemented:

The manipulator is required to have a low self-weight. This enables the operator to move the system through the facility. In some cases the support of a trolley might be useful.

Furthermore a modular layout allows the operator to move the manipulator through small and narrow openings by disassembling it partly.

In this case a low single-weight of each module is essential to allow lifting them by one person only.

Moreover the disassembly as well as assembly of the manipulator should be feasible in a very short period of time. Therefore the use of quick fasteners is recommended. The entire system has to be flexible and rugged.

In order to meet the performance requirements an output of at least 10 m² per hour is essential and

the minimum requirement of the clients.

Beyond that an autonomous operation of the manipulator is advisable to keep the labour costs on a low level.

Not less important are safety features that assure a safe operation of the entire system. Here an emergency shut-off is the minimum requirement.

But due to the fact that the manipulator can be operated on walls and ceilings by means of vacuum technology it is also a prerequisite to prevent the system from falling off the object that is being treated.

In this regard pressure monitoring and the use of check valves is important.

Furthermore the control system needs a proper set up that includes safety procedures.

4 MACHINE BUILD-UP

4.1 Basic System AMANDA I

According to the basic idea, a first manipulator system was built in the course of the research project AMANDA.

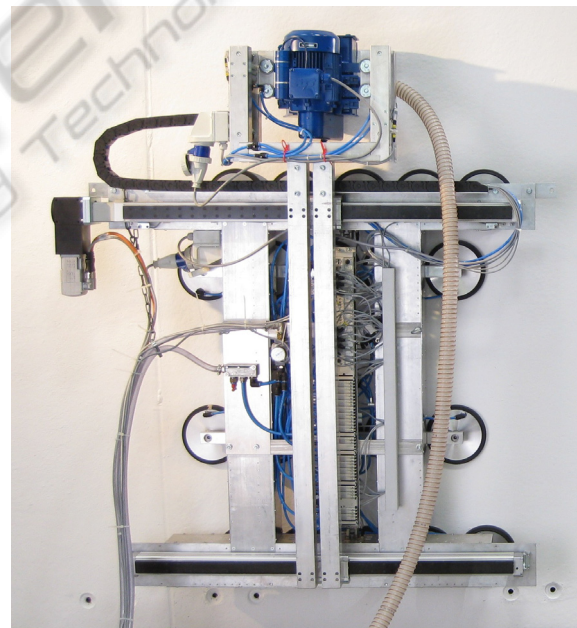


Figure 1: AMANDA I in wall operation.

AMANDA stands for **A**utonomous **M**anipulator for **D**econtamination **A**ssignments. The system can be operated on walls and ceilings by using vacuum technology. It is equipped with a milling attachment for decontamination purposes.

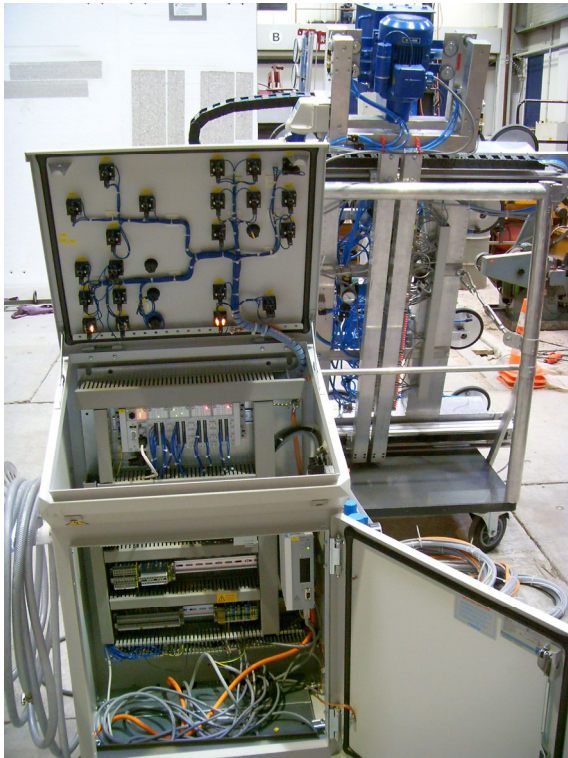


Figure 2: AMANDA I with control unit.

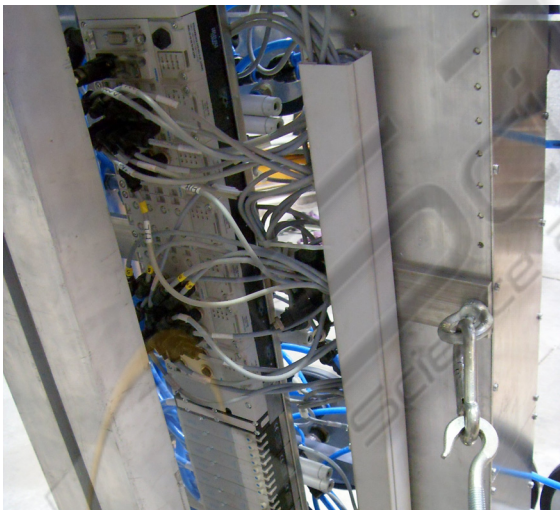


Figure 3: CPX Valve Terminal of AMANDA I.

The control unit which is shown in figure 2 is based on a FESTO SPS. It is mounted in a switch box underneath the control panel. The SPS is linked with the CPX valve terminal on the manipulator via cable. All pneumatic valves as well as all sensors for the positioning of the pistons and for pressure monitoring are connected to the CPX valve terminal. The valve terminal is shown in figure 3.

In contrast to the valves and sensors, the servo drive which moves the linear drive unit is directly linked with the SPS by cable.

4.2 Successor System MANOLA

Based on the principle of the stand-alone manipulator for decontamination assignments AMANDA I the successor system MANOLA is currently under construction at the KIT. MANOLA is funded by the German Ministry for Education and Research under the reference key 02S8548.

MANOLA stands for **M**anipulator **O**perated **L**aser **A**blation. The support system is operated with vacuum technology as well. Instead of a milling attachment MANOLA carries a laser system that is used for the ablation of both, contaminated and uncontaminated concrete surfaces and coatings. MANOLA is built according to the specifications listed in section 3.

To allow the transportation of MANOLA inside of a nuclear facility the system is equipped with a trolley. The trolley consists of an undercarriage fitted with rubber tracks, and a loading platform. Figure 2 shows a visualization of MANOLA in wall operation. Beyond that, MANOLA can be operated on ceilings as well.

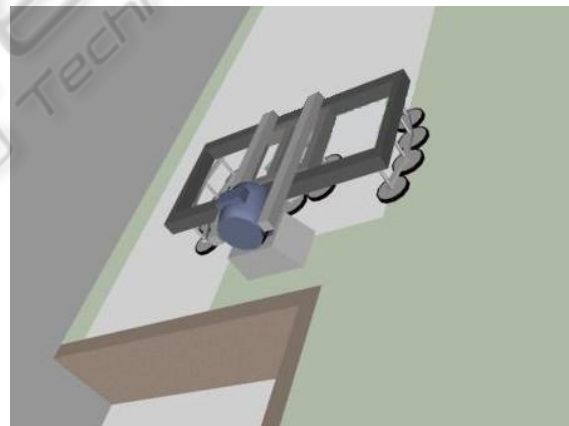


Figure 4: MANOLA in wall operation.

5 MANOLA CONTROL UNIT

5.1 Processor And Chassis

The control unit of MANOLA is based on the CompactRIO System that is distributed by National Instruments. ‘National Instruments CompactRIO is a small rugged industrial control and acquisition system powered by reconfigurable I/O (RIO) FPGA

technology for ultrahigh performance and customization. NI CompactRIO incorporates a real-time processor and reconfigurable FPGA for reliable stand-alone embedded or distributed applications, and hot-swappable industrial I/O modules with built-in signal conditioning for direct connection to sensors and actuators' (National Instruments, 2009).

The setup of the system applicable for MANOLA consists of an embedded real-time processor with 800 MHz, 512 MB DDR2 RAM, and 4 GB storage. The processor is connected to a 4-slot Virtex-5 LX50 reconfigurable chassis that will be installed on the MANOLA trolley. Furthermore two 8-slot deterministic chassis will be installed on the manipulator itself for embedding all sensors and actuators of MANOLA. Both chassis on the manipulator will be linked with the main chassis on the trolley in daisy chain mode via Ethernet cable, and the main chassis on the trolley is linked via WLAN with a laptop that serves as the MANOLA Control Panel. Beyond all these components there are WLAN cameras installed on each, the trolley and the manipulator, for process monitoring by the operator.

5.2 Sensors

Various sensors are part of the MANOLA control system. They are used for different purposes like positioning, vacuum and pressure monitoring, position monitoring of pistons as well as scanning and evaluating the object which has to be treated. All sensors provide necessary input to the manipulator for a proper operation.

First, there are four distance laser sensors used as a simplified positioning system for MANOLA. The four sensors are fixed to a traverse that carries the laser processing head and runs over the main frame of the manipulator. By moving the distance laser sensors over the entire frame, many different reading points can be generated and used to map the borderlines given by adjacent parts of the building.

Second, a laser scanner is used for scanning and evaluating the surface area of the object to be treated. The laser scanner is part of the processing head which also includes the optics of the laser unit for the ablation process, and it enables the machine to detect disruptive objects like offsets on the surface, nails, screws, pipes, etc. All these different kinds of objects may interfere with the operation of the laser. Thus it is very important to detect them in order to protect the laser processing head.

Third, there are two ultrasonic sensors attached to the processing head. The ultrasonic sensors are

used for the detection of obstacles that may appear in front of the processing head during treatment of the surface area. In any case of interference the process will be paused immediately in order to protect the processing head. Then the processing head will be moved up by an electric drive and the suspect area will be scanned with the laser scanner if applicable. Depending on the size of the obstacle the manipulator will be moved forward or around the localised object. The integrated decision making process is based on the input of the various sensors of the processing head.

Fourth, pressure and vacuum monitoring is an essential part of the control system. Due to the fact that the manipulator is operated with vacuum technology it is security-relevant and prevents MANOLA from falling off the wall. The vacuum for the suction plates is produced by sending pressurized air through vacuum generators that operate according to the Venturi Principle. Because the connection of the suction plates to the object depends on the pressure as well as on the vacuum, both, pressure and vacuum, need to be monitored.

Fifth, several small size sensors are required for monitoring the exact positions of the pistons of all pneumatic cylinders. Every time when a piston is moved the control system asks for a feedback, if the piston reached its destination. If this case is true, further operations can proceed. In a false case, further operations have to be put on hold due to the occurrence of an error. Only after assessing and removing the error by the operator further operation may proceed.

5.3 Actuators

Besides the sensors MANOLA includes different actuators. The actuators are used for the operation of the supporting frame, the traverse and the processing head. The actuators of MANOLA are a rack drive, a rotary module, a servo drive as well as a couple of pneumatic control valves.

The rack drive joins two important tasks. It moves the traverse and processing head for ablation processing as well as the supporting frame which includes the main frame and sub frame for pacing. By linking the rack drive to the component that has to be moved only one drive is needed. Thus the overall weight of the manipulator is kept on a low level.

In order to turn the manipulator by 45, 90 or any degrees to change the direction of processing a rotary module is built-in to the center of the sub frame. When the manipulator is rotated the suction

plates of the main frame are released from the object, e.g. a wall, and the rotary module can be activated. After the manipulator is moved into its final direction, the suction plates of the main frame are sucked to the object again. During the whole rotation process the suction plates of the sub frame stay in contact with the object (wall, ceiling, etc.).

As described in the previous section, the processing head is moved down for processing the surface area and moved up when the processing is paused or finished. Lifting and kneeling is executed by a servo drive. Therefore the servo drive is mounted between the outer end of the traverse and the processing head. Input generated by the laser scanner and the ultrasonic sensors provide necessary input for the control system to actuate the servo drive. Beyond that further input is provided via control panel by the operator.

Last but not least a couple of pneumatic valves are integral part of the pneumatic system and the vacuum system. During pacing the relevant pneumatic valves are activated. They control the airflow necessary for the pneumatic cylinders and the vacuum generators. Owing to the fact that the pneumatic valves must not change their operating status in case of a drop of voltage, bistable valves are being used.

5.4 NI-Modules And Connectors

All actuators and sensors have to be linked with the control unit. Due to the great variety of connector types this requires an adaptable system. This is implemented by using the cRIO-System with its many different NI-Modules that all fit in the same type of chassis. The cRIO chassis provides the chance to build in the relevant type of NI-Modules depending on the attachment and its relevant NI-Modules.

Table 1: MANOLA NI-Modules.

Pos.	Module	Connector Type	Device
1	NI 9201	Analog IN	Sensor
2	NI 9205	Analog IN	Sensor
3	NI 9263	Analog OUT	Actuator
4	NI 9421	Digital IN	Sensor
5	NI 9425	Digital IN	Sensor
6	NI 9472	Digital OUT	Actuator
7	NI 9477	Digital OUT	Actuator
8	NI 9853	CAN BUS	Actuator
9	NI 9870	RS 232	Sensor
10	NI 9871	RS 485	Actuator

As quick as the attachment can be changed the NI-Modules can be switched as well, even during operation. That keeps the system flexible and aligned with the customers needs. The following table provides you an overview of all existing connector types and the relevant NI-Modules.

6 CONCLUSIONS

Especially in areas where people are exposed to great hazards, the use of a manipulator provides an interesting solution. Nuclear facilities are one of those fields of application. Beyond that there are other areas as well where the use of a manipulator can be valuable. For example this applies to high structures that require costly scaffolding or other areas that are difficult to access.

By providing a compact, light and robust unit equipped with a milling attachment or laser, the customer disposes of a suitable machine for the treatment of various kinds of surfaces. Furthermore the manipulator comes with an intelligent and adaptable control system that provides a customer friendly operability as well as expandability.

Relating to feedback of project managers in nuclear facilities under decommission, the use of manipulators is more than welcome and thus will be common in the future. The same is expected for other fields of use. But in order to meet these needs the current manipulator needs to be further developed. Thus the system provides a platform which is capable of being extended in the future.

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