Actual Research and Development Activities in the Field of Dismantling

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The shutdown of nuclear facilities is attracting more and more public attention, not only because of their limited life cycle, but primarily due to the political decision to phase out nuclear power. For the engineers involved, the complete deconstruction and decommissioning of such facilities represents an extremely complex problem with countless constraints and variables which have constantly to be taken into account and incorporated into the process. Deconstruction work often relies on standard construction equipment, but this has to be modified and refined for each application and for each part of the structure.

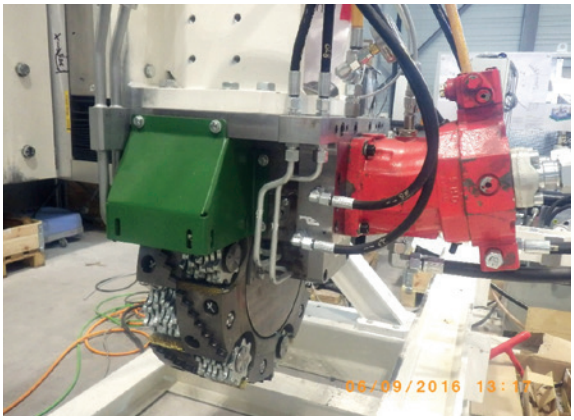

Fig. 1.
Patented novel milling cutter to remove highly reinforced concrete.

The deconstruction costs run into several hundred million euros, depending on the actual design of the power station, and the demolition work itself takes about ten years. The phasing out of nuclear energy and the attendant switching off of Germany's nuclear power stations by 2022 have focused public attention even more on this particular issue. More than 440 nuclear power stations are in operation around the globe, and they will all need to be decommissioned at some point. These facts serve to illustrate the great potential and the vast amount of research which this field entails.

The professorship of Deconstruction and Decommissioning of Conventional and Nuclear Buildings at Karlsruhe Institute of Technology (KIT) was established in 2008 and is dedicated exclusively to the last life cycle of a building, its deconstruction and decommissioning.

There is no doubt that a nuclear power station can be safely decommissioned nowadays. Neither is there any doubt that optimization potential exists for many technologies and processes. There is also scope to further enhance the effectiveness of the automation and the robotics.

This is precisely where this department comes in, concentrating its efforts on R&D projects, and always working in close collaboration with industry. These projects can then be comprehensively tested in the Institute's own testing facility.

The individual R&D projects address the following issues:

- Reduction of secondary waste
- Automation and remote operation of the processes
- Performance optimization of existing processes
- Development of new technologies
- Management methods for decommissioning and deconstruction

By way of example, we present a brief overview of the DefAhS (Defined ablation of highly reinforced concrete structures) project, a collaborative project between Kraftanlagen Heidelberg GmbH, Herrenknecht AG, and KIT. The project objective was the in-depth removal of highly reinforced concretes using one single tool and in one single operation. In 2019, the project achieved 2nd place in the Innovation Awards at the Bauma, the world's largest construction machinery trade fair, and the innovation has been granted patents in numerous countries. The equipment innovatively combines cutting tools for concrete and steel in one milling drum. For the first time ever, it is now possible to automate the deep milling of cracks, for example.

Another of our current projects is MASK (Magnetic Separation Method for the Reduction of Secondary Waste from the Water Abrasive Suspension Cutting Technique (MASK)), because the cutting up and disposal of the reactor pressure vessel (RPV) and its related installations poses a considerable challenge during the decommissioning of a nuclear facility. One of the cutting techniques is the Water Abrasive Suspension Cutting Technique (WASS), which is characterized by the high degree of flexibility of its modular application and the fact that it is impervious to the mechanical and thermal stresses in the material being cut. The abrasive that has to be

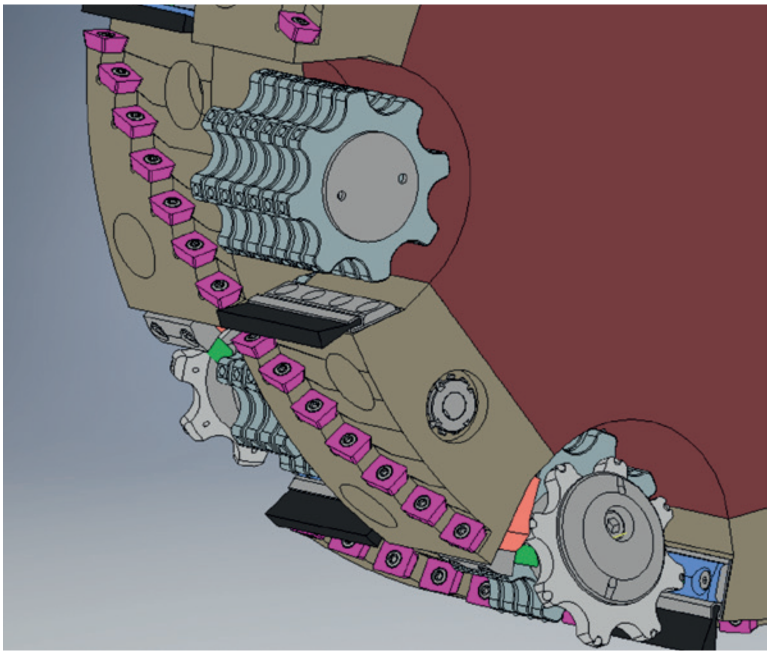

Fig. 2.
Detail of the combination of impact cutters and steel cutting inserts.

Fig. 3.
Prototype rig for the separation.

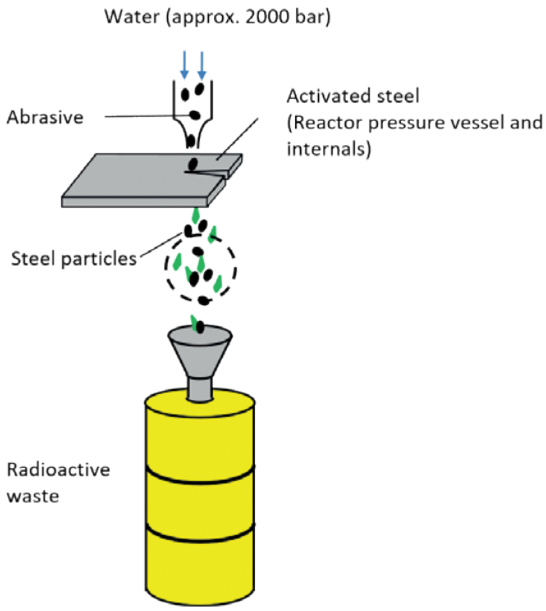

Fig. 4.
Secondary waste: generation.

admixed to facilitate the cutting process combines with the metal cuttings from the RPV, and this mixture itself has then also to be disposed of. The amount of secondary waste produced thereby is considerable, roughly doubling the total volume of radioactive waste. The disposal of secondary waste is very expensive and so this method of cutting up the reactor pressure vessel has fallen out of use despite its technical advantages. MASK was preceded by the research project known as NENAWAS (New Disposal Methods for the Secondary Waste of the Water Abrasive Suspension Cutting Technique), a close collaboration between KIT and AREVA GmbH which succeeded in developing a separation method which can process the secondary waste from the water abrasive suspension cutting technique. It utilizes a prototype magnetic separation rig to separate the metal cuttings from the mixture of steel and abrasive material produced in the cutting process. The microscopic analysis of the separated abrasive shows that it is still contaminated with metal cuttings, however. Before the bulk of the secondary waste can be cleared for release, further investigation is required, and this is being done in the current MASK project. The objective here is to undertake basic research which allows the quality of the separation to be optimized to such a degree that the secondary waste can be disposed of in a conventional manner and thus allow the cutting technique to be used in the future for the large number of decommissioning projects still to be undertaken. To this end, further experiments (with different types of steel to be cut and different processed mixtures) are being carried out on the existing test rig. Moreover, a numerical flow simulation of the magnetic filter is being produced. In the controlled area of the laboratory belonging to our project partner (Institute for Nuclear Waste Disposal), the separation is being tested and evaluated under realistic conditions with a small, laboratory-scale test setup with active and activated materials to assess its suitability for the treatment of the radioactive waste.

Robotics is also making greater and greater inroads into the field of deconstruction and decommissioning. This has led to the setting up of the ROBDEKON (Robotic Systems for Decontamination in Hazardous Environments) project, a competence center dedicated to research into fully autonomous and semi-autonomous robotic systems. The aim for the future is for such systems to carry out decontamination work autonomously, obviating the need for humans to enter hazardous zones. As of mid-June 2018, the Federal Ministry of Education and Research has provided ROBDEKON with twelve million euros of funding as part of the »Research for Civil Security« program. It will initially run for four years, but the aim is for the competence center to continue in the long term. ROBDEKON is coordinated by the Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB. In addition to the Fraunhofer IOSB, other research institutions involved in the project are Karlsruhe Institute of Technology (KIT), the German Research Center for Artificial Intelligence (DFKI), and the FZI Research Center for Information Technology. The industrial partners in the consortium are Götting KG, Kraftanlagen Heidelberg GmbH, ICP Ingenieurgesellschaft Prof. Czurda und Partner mbH, and KHG Kerntechnische Hilfsdienst GmbH.

The intention is for ROBDEKON to become the national point of contact for issues appertaining to robotic systems for decontamination in hazardous environments. The competence center aims to set up a network of experts and users, and create an innovative environment for new technologies for robot-assisted decontamination for its partners from science and industry.

ROBDEKON has been established to explore and develop novel types of robotic systems for decontamination tasks. Its research topics are mobile robots for difficult terrain, autonomous construction equipment, robotic manipulators, and also decontamination concepts, planning algorithms, multi-sensorial 3D environment mapping, and teleoperation by means of virtual reality. Methods from the field of artificial intelligence enable the robot to perform the tasks assigned to it either autonomously or semi-autonomously. While

Fig. 5.
Prototype of automated milling system.

the competence center is being set up, the work will initially concentrate on three relevant areas of application: the remediation of landfills and contaminated sites, the decommissioning and deconstruction of nuclear facilities, and the decontamination of facility components. By involving users at an early stage, we ensure that practical systems which reduce the risk for human operators and protect them from hazards are developed expeditiously.

The Department of Deconstruction and Decommissioning of Conventional and Nuclear Buildings at Karlsruhe Institute of Technology is to explore and develop an approach that will help find a solution which uses robotic systems for the automated decontamination and clearance measurement of building structures in nuclear facilities. Automated decontamination focuses on treating a contaminated concrete wall and contaminated indoor spaces with the aid of a mobile work platform.

To this end, the department is developing and constructing an automated surveying system which will utilize the latest measurement systems to explore its surroundings. It will display the contaminated locations on a 3D chart of its environment as a function of the radiation level, thus allowing the subsequent decontamination work to be carried out with greater efficiency.

This overview is intended to show that R&D work is still required in the field of nuclear facility decommissioning, even in 2020. The emphasis here is always on the involvement of, and close collaboration with industry, since this is the only way to work out a practical solution.

In addition to issues relating specifically to nuclear facilities, great importance is also attached to all aspects concerning the demolition of conventional buildings. Some brief details are provided below. Basically, the waste products from the demolition process (asphalt, concrete, masonry, asbestos, man-made mineral fiber, …) are categorized as either hazardous or non-hazardous waste. The laws, ordinances and guidelines are extremely extensive, specific to a particular federal state in some cases, and subject to continual revisions and amendments. The thresholds above which asphalt is classified as hazardous waste differ by several hundred mg PAH/kg across the individual federal states, for example.

The figures stated below show just how important the demolition of conventional buildings is. In Germany, around 209 million tonnes of waste are classified as „construction and demolition waste“ every year. In 2015, this amounted to over 50 percent of the total waste produced (402.2 million tonnes). In conjunction with the Circular Economy Act (Kreislaufwirtschaftsgesetz) and the stipulations on recycling rates, this fact clearly emphasizes the considerable research potential in this field. The research topics addressed are the automated separation of different types of waste, optimization potentials in relation to environmental release and pollution during demolition, and also automation and remote handling. This relates in particular to the handling of "hazardous waste". The task is to recognize these potentials, develop optimization approaches, and implement pilot projects with a specific objective.

Selective demolition requires that questions about how to handle hazardous waste and pollutants, and how to comply with the stipulations regarding type-specific collection and disposal of the demolition material, be clarified in advance. All these issues mean the demolition of conventional buildings is an exciting field with extensive research potential.

The redevelopment of existing building structures and building on "brown field sites", too, will become ever-expanding fields of research in the future. To do justice to the demands, the Department of Deconstruction and Decommissioning of Conventional and Nuclear Buildings is addressing this future-oriented field in its research, science and teaching. Now more than ever, the graduates of today must have a good general grounding in topics such as the construction, operation, and also the decommissioning of buildings. To illustrate this, we have included part of a survey carried out at universities and universities of applied sciences on the topic of "demolition-related course content in civil engineering". The survey reveals that "demolition" and "decommissioning" and other related subjects are not covered in detail. Lectures on more detailed issues of decommissioning and deconstruction are not usually part of the curriculum.

This is precisely where we come in, by offering lectures which train young graduates in these important and sustainable subjects.

The deconstruction and decommissioning of conventional and nuclear buildings is therefore a discipline whose graduates will be in great demand and which will guarantee secure employment in the future.

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