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Development of a mobile, automated, optical inspection system for radioactive drums

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Abstract

Due to the delayed construction and commissioning of a German repository for intermediate and low-level radioactive waste, waste inventories dating back several decades are now located at interim storage sites, and their safekeeping must be ensured even for an indefinite period of interim storage.

Since the publication of reports of corroded drums in the interim storage facility of the Brunsbüttel nuclear power plant, in March 2012, and the interim storage facility of Kerntechnische Entsorgung Karlsruhe GmbH (formerly Wiederaufarbeitungsanlage Karlsruhe GmbH), the need for an inspection system for continuous monitoring of the stored inventories has become apparent, to ensure permanently safe storage.

The usual practice in the interim storage facilities is recurrent inspections, which are almost exclusively carried out manually and without electronic comparative recordings or machine documentation and archiving. The remote or automated inspection does not take place. The inspections are carried out visually and are therefore very subjective and therefore subject to errors. Manual performance is labor-intensive and requires the use of personnel exposed to radiation. Neither are uniform inspection criteria of the visual inspections applied, nor are the inspections performed uniformly between sites.

Based on these facts, the Institute for Technology and Management in Construction, Department of Deconstruction and Decommissioning of Conventional and Nuclear Buildings, is developing an automated drum inspection system within the framework of the funding measure FORKA - Research for the Deconstruction of Nuclear Facilities and in cooperation with the Institute of Photogrammetry and Remote Sensing (IPF) of KIT. This procedure makes it possible to determine and document the current condition of individual drum containers in a uniform reproducible manner. Research and development work within the project will help to increase the safety of extended interim storage.

The new inspection system EMOS - Development of a mobile, automated, optical inspection system for radioactive drums - is listed under the BMBF funding code 15S9420 and will be processed in the period from 2020 to 2022.

Introduction

In Germany, the decommissioned iron ore mine Schacht Konrad in Lower Saxony is currently being developed by the Bundesgesellschaft für Endlagerung mbH (BGE) into a repository for radioactive waste with negligible heat generation. Until Konrad is commissioned, the low- and intermediate-level radioactive waste with negligible heat generation will be stored in federal-state collection facilities, in research facilities, at the sites of nuclear power plants or other nuclear sites, and in central interim storage facilities operated by the Bundesgesellschaft für Zwischenlagerung (BGZ). There, the waste must be conditioned according to its type and radioactive inventory, i.e., it must be processed, packed in suitable containers in each case, and documented so that it can meet the acceptance conditions of the Konrad repository and be delivered there safely by the regulations for the transport of hazardous materials.

Following the applicable guidelines, including BMUB Waste Control Guideline 3-59 [1] and 3-60 [2], radioactive waste must be conditioned and documented in a manner suitable for final disposal, stored securely, monitored, and periodically inspected for damage. Among other things, specifications for the inspection of waste packages in storage are mentioned. "Accordingly, the licensee shall verify the continued existence of the safety-relevant properties of the waste or waste packages for the duration of the interim storage by representative inspections at appropriate intervals. For this purpose, representative packages shall be kept accessible for visual inspection" [1].

In the recommendation of the Waste Management Commission (ESK) "ESK Guidelines for the Interim Storage of Radioactive Waste with Negligible Heat Generation" [3], requirements for interim storage facilities and their operation are named, within which principles for the monitoring and periodic inspections of the waste are also formulated: "If it must be assumed during interim storage that the retention properties of the waste packages are subject to a relevant change over time, measures must be taken for the timely detection of adverse developments. A concept shall be developed for this purpose." (...) "In this context, the waste packages may be placed in the storage facility in such a way that they can be made accessible if necessary and visual tests or inspections can be carried out. Alternatively, visual examinations and inspections on reference drums are permitted and are performed if, for example, inspections directly on the waste drum would lead to relevant radiation exposures due to the high local dose rate. From the condition of these reference packages, the condition of the remaining waste packages is inferred" [3].

In the course of the implementation of the ESK guideline, the Lower Saxony Ministry for the Environment, Energy, Construction and Environmental Protection has published a document explaining the current situation of the recurrent inspections practiced at Lower Saxony repository sites [4]. In summary, only visual inspections are carried out. Likewise, inspections of a subset of the drums and reference drums are frequently applied in practice. In 2015, within the ESK statement "Implementation of the ESK Guidelines for the Interim Storage of Radioactive Waste with Negligible Heat Generation", a summary was made on the current status of recurrent inspections performed in interim storage facilities [5]: "As a result [...] it can be stated that inspections are performed very differently. The spectrum ranges from a complete inspection of all drums, inspections of accessible outer surfaces, of reference drums to the restriction of inspections to drums with pre-existing damage and inspections during storage and retrieval operations. The time intervals between the individual inspections also vary. Another result [...] is that the documentation of inspections of radioactive waste packages is also carried out very differently" [5]. The ESK formulates as a result that a prognosis on the longer-term storability of waste packages is only possible if compliance with the guidelines [3] can be assumed. With the existing high number of old and raw wastes, it cannot be ruled out that further findings will occur in the next few years. Therefore, the ESK particularly refers to the aforementioned recommendations regarding a detailed inventory of radioactive waste with corresponding qualification and monitoring concepts [5].

The EMOS project with its automated inspection unit is based on this common inspection practice and the existing potential for improvement. It contributes to an optimization of the recurring inspections through standardization and reproducibility while simultaneously increasing occupational safety.

Inspection System

EMOS is a mobile inspection unit that remotely and automatically records the entire drum surface, including lid and base, optically, evaluates it analytically, and both electronically stores and outputs the results in the form of an inspection report. In this way, recurring inspections of the drum stock can be completed under the same test conditions each time, and changes in the drum geometry and surface condition (e.g. corrosion formation, etc.) can thus be detected. A decisive advantage is the possibility of carrying out the inspection remotely to reduce the radiation dose to the employees on site. The optical evaluation, display, and output of the results will ensure a more precise inspection and analysis of the drum surfaces through software to be specially developed than is possible by manual and visual inspections as currently performed in the interim storage facilities. The continuous monitoring of the stored drums will be facilitated and also the tracing of a possible damage development through the comparison of archived measurement results is a novel and powerful tool that helps to increase and ensure the safety aspects of interim storage in the long term. Corrosion damage can be identified at an early stage with the help of the inspection unit and measures can be taken at an early stage to counteract the loss of integrity of the storage containers.

The operating principle of EMOS system is shown in Figure 1a/1b. The main features of the inspection system include:

1. 20ft high cube container with side roller door;
2. roller conveyor belt;
3. turntable;
4. drum tipping unit;
5. linear unit;
6. sensors (cameras, light section sensor);
7. lighting.

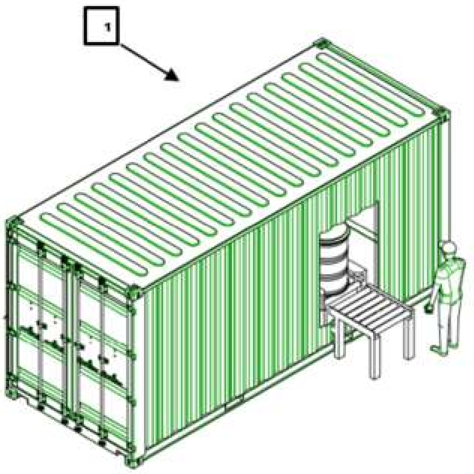

Figure 1a – 20ft High Cube Container

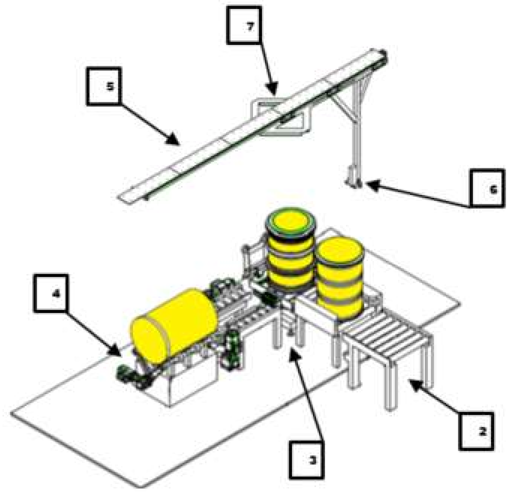

Figure 1b - Inspection system

To achieve optimal measuring conditions and to keep the inspection unit mobile, it is aimed to execute the entire system in a closed 20ft high cube container with a side roller door. In this way, transport to and within the intermediate storage facilities is possible.

The chosen container unit is "200-liter drums", which are used because of their easy availability and good manageability. To check a drum unit, it is brought onto the external roller conveyor using existing building technology, e.g. overhead crane or forklift truck.

The system is controlled via the control panel, which enables remote handling of the complete sequence. There are 3 main commands on the control panel: "Drum on the turntable", "Drum on tipper" and "Drum return". After selecting and pressing the main commands, the drum moves to the respective position. After reaching the main position, further pushbuttons on the control panel are used to decide between further sub-commands. The sub-commands are as follows: "Scan drum shell", "Scan drum lid", "Photograph drum shell", "Photograph drum lid", "Scan drum base" and "Photograph drum base".

After selecting the main command, the drum is conveyed to the turntable and centered. For the duration of the measurement to be performed, the lateral roller shutter is automatically closed after the drum bundle has been placed in the container. This allows almost complete darkening of ambient light and interfering light influences.
Various sensors are integrated on the linear unit, a three-dimensional light-sectioning system, and two cameras that collect data to identify and report abnormal drum conditions. This detection system is

designed to identify and report two categories of drum defects: Geometric defects and surface changes (e.g., corrosion spots, paint chips, etc.). In addition, it is designed to report only new or changing defects. For example, each time a drum is inspected, the current condition is compared to a baseline defect list compiled from previous inspections. This trend-based method reduces the amount of data to be stored during an inspection and protects against reporting false alarms.

After selecting the sub-command "Scan drum shell/drum lid", the drum is rotated 360° on the turntable and imaged using a three-dimensional light-sectioning method. A laser class 2 profile scanner is used for this purpose. With the aid of a laser line projected onto the rotating drum, geometric defects such as surface dents and dings are detected. A light section sensor scans the surface of a drum profile by profile. The projected laser lines are recorded by a camera integrated into the sensor. The evaluation is based on the principle of triangulation and is performed in real-time within the sensor. As a result, three-dimensional coordinates of the profile points are obtained. By relative movement between the sensor and the drum (e.g. on the turntable) and the assembly of many individual profiles, the entire drum surface can be recorded in three dimensions. Figure 2a shows an example of a post-processed representation of a new drum. Figure 2b shows a post-processed representation of a damaged drum. The color scale represents the following facts in Figure 2b: In the areas of a dark coloration (dark blue), it is a dent compared to the original drum geometry; in the areas of light coloration (yellow), a bulge/bump outward is shown. When new defects are found, the governing parameters (location and size) are recorded.

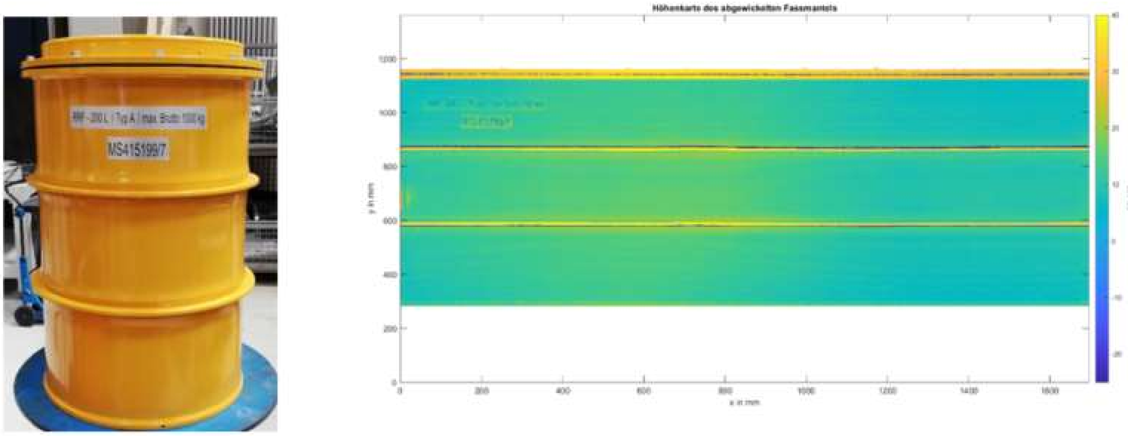

Figure 2a - Height map of the unwound drum shell - New drum (Source: M. Müßle, IPF, unpublished)

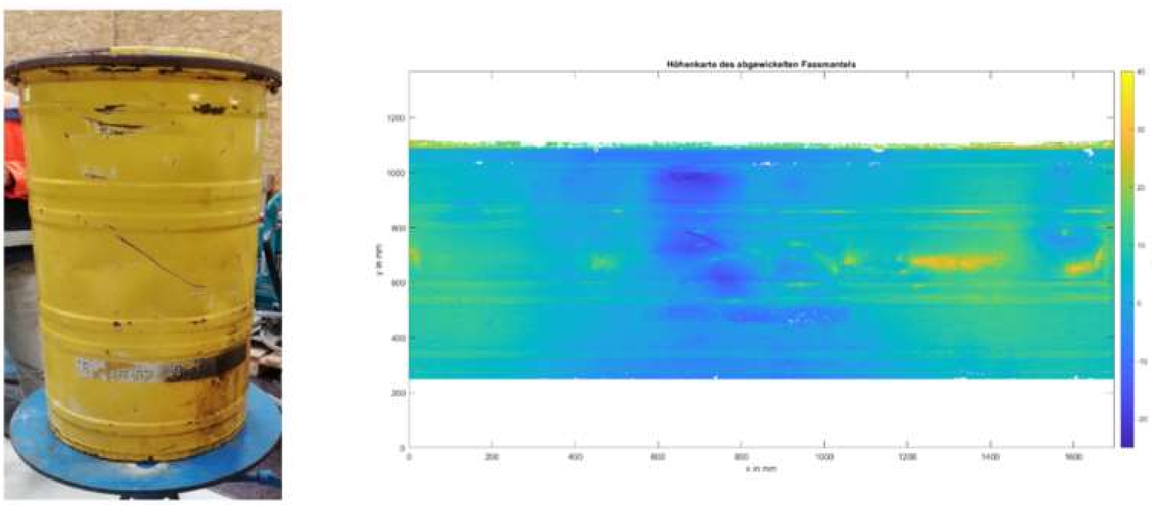

Figure 2b - Height map of the unwound drum shell - damaged drum (Source: M. Müßle, IPF, un-published)

After selecting the sub-command "Photograph drum shell/ drum lid", the drum is rotated 360° on the turntable and simultaneously optically recorded using cameras. Based on the images, the drum shell and drum lid are examined for the smallest optically visible changes in the surface structure; corrosion defects become visible and can be localized.

Corrosion defects include rust stains, rust streaks, and areas of blistering, spalling, flaking, or missing paint. These defects are detected using a color vision system consisting of two color cameras and multiple LED lights. Within the container, artificial lighting can then be used to provide uniform and optimal lighting conditions for image acquisition. This greatly reduces reflections and shading on the drum surface, which could lead to incorrect analysis. Images from the drum are collected and sent to integrated image processors for color analysis. New defects found are recorded by size and location. Figure 3 shows two examples of laser profiles of the drum lid with projected images in plan view. These serve as the basis for drum lid inspection.

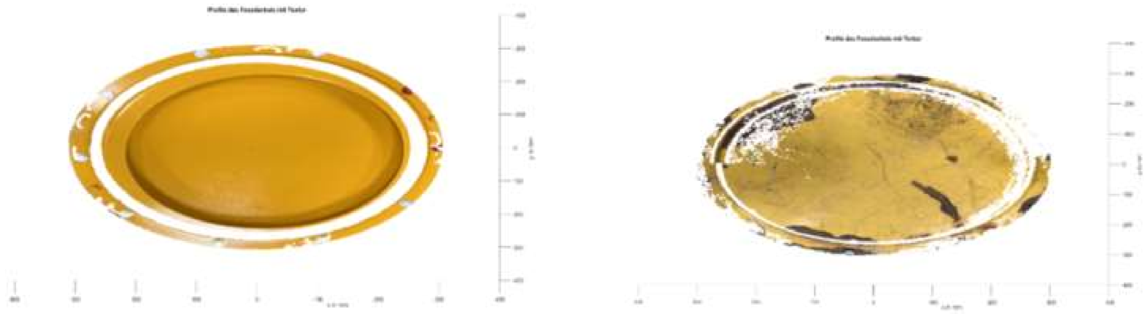

Figure 3 - Profiles of the drum lid with texture (Source: M. Müßle, IPF, unpublished)

After selecting the main command, the drum is conveyed to the drum tilting unit and tilted 90° into the horizontal. To ensure optimum measurement, a distance from the outer edge of the drum shell to the sensors between a minimum of 900mm and a maximum of 1200mm is required. For this reason, when the drum is lying horizontally on the tipping station, the sensors are moved up using a linear unit to ensure this distance requirement. On the tipping station, the drum is rotated 360° around its axis and the bottom of the drum is scanned, automatically illuminated, and photographically recorded after the appropriate sub-command has been selected. When the complete inspection has been performed, the drum is retracted after selecting the main command.

Conclusion

The EMOS research project is planned to be carried out in a total of 10 phases, ranging from a basic analysis, a concept study, an experimental phase with final construction of a demonstrator (Demonstrator 1.0), and a final test and validation phase to a technically mature inspection unit (Demonstrator 2.0). Four milestones mark the most important sub-steps of the project: the completed concept (M1), the initial demonstrator unit 1.0 (M2), the mature system (M3), and the mature demonstrator unit 2.0 (M4). The project is planned to run from January 2020 to December 2022 and is on schedule. The first demonstrator will be completed in June 2021. This will mark the beginning of the fine-tuning and testing phase of the first demonstrator. For a possible follow-up project "EMOS 2", there is the possibility of integrating a radiation dose measurement that takes place directly in the measurement container and examines the drum containers in this respect. This should provide an even wider range of data on the classification of the drum containers to further increase safety in the handling of drum containers in interim storage facilities. Due to a large amount of accumulated and accumulating low and intermediate-level radioactive drums that will only be disposed of in the coming decades, the need for improved control options in interim storage will increase over time. The goal is to reduce subjective visual inspection by individual employees in the direct contact area and to enable automated, remote, objective, and standardized assessment.

Literature References

[1] Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMUB), Lagerung, Handhabung und innerbetrieblicher Transport radioaktiver Stoffe (mit Ausnahme von Brennelementen) in Kernkraftwerken, Sicherheitstechnische Regel 3604, 1989.

[2] Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMUB), Bekanntmachung der Richtlinie zur Kontrolle radioaktiver Reststoffe und radioaktiver Abfälle, 2008.

[3] Entsorgungskommission (ESK), „ESK-Leitlinien für die Zwischenlagerung von radioaktiven Abfällen mit vernachlässigbarer Wärmeentwicklung," Bonn, 2013.

[4] Niedersächsisches Ministerium für Umwelt, Energie, Bauen und Klimaschutz, „Übersicht der Lagerstandorte für radioaktive Abfälle in Niedersachsen," 2015.

[5] Entsorgungskommission (ESK), „Umsetzung der ESK-Leitlinien für die Zwischenlagerung radioaktiver Abfälle mit vernachlässigbarer Wärementwicklung," 2015.