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MEXT's Nuclear Joint Research Collaboration

漏洩箇所特定とデブリ性状把握のためのロボット搬送超音波インテグレーション

Study of an ultrasonic measurement system and its robotic deployment into vessels for the combined assessment of debris condition and water leakage

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The inspection of PCV/RPV in Fukushima Dai-ichi NPP presents a wide range of engineering challenges due to limited access and the harsh radioactive environment. Therefore, for decommissioning purpose, we proposed a deployment and manipulation system for the ultrasonic sensor robot considering the condition of the vessels. An ultrasonic measurement system which is integrated with a robot arm was used for identifying water leakage and determining a fuel debris distribution. Some experimental results of water leakage identification and shape reconstruction are briefly discussed.
Keywords: Ultrasonic Velocity Profiler (UVP), Robot, Flow Mapping, Shape Reconstruction

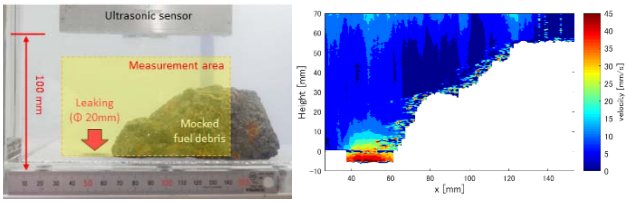
1. Introduction

After the Fukushima Dai-ichi NPP accident, a significant amount of radioactive material was released into the atmosphere, and three of the plant's six reactors suffered core meltdowns (unit 1, 2 and 3). The long-term goal is to decommission the damaged vessels. Nevertheless, before starting the decommissioning process, the highly radioactive fuel debris must be removed from the PCV and RPV. However, at present relatively little is known about the state of the vessels and the location and distribution of the fuel debris. Therefore, in this study, we proposed an integrated system of the robot and ultrasonic measurement. Ultrasonic measurement is considered as a promising non-optical inspection method since it can be used in opaque liquids. Furthermore, ultrasonic transducers are suited to high radiation levels. Present study, an ultrasonic velocity profiler (UVP) and total focus method (TFM) are performed on identifying leakage points and determining the distribution of fuel debris, respectively.

2. Test facility and experimental results

2.1 Shape reconstruction by TFM method

An ultrasonic velocity profiler (UVP) and total focusing method (TFM) was developed for qualitatively identifying leakage location and fuel debris distribution [1]. Experiments were conducted to evaluating the performance of the developed system as showed in Fig.1 (a). As a result, the shape of the mocked fuel debris and location of leakage point are determined and assumed as a white line and intensive downflow (red), respectively in Fig.1 (b) and those show a good agreement with the actual shape and location. Thus, applicability of the methodology is confirmed.

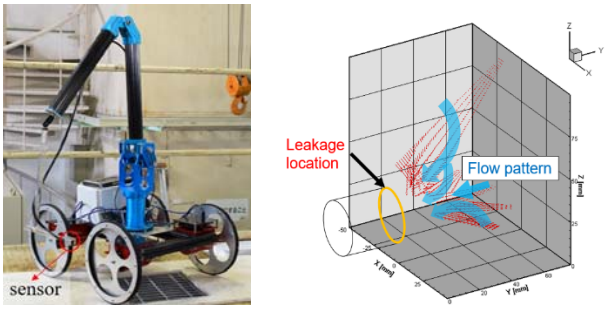


(a) Measurement area. (b) Combined image.

Fig. 1 Shape reconstruction of imitated fuel debris by TFM method.

2.2 Identifying a water leakage by phased array UVP

A robotic arm with a combination of phased array UVP technique was developed [2]. For the confirmation of the phased array flow mapping using the robotic transportation, water flow into a leakage hole was measured. Figure 2 (a) shows the robot arm and ultrasonic sensor and Fig. 2 (b) shows a flow mapping on identifying a water leakage location. Flow towards the leakage hole is observed. Therefore, the possibility of the water leakage location measurement using the robot arm and phased array UVP is confirmed.



(a) Robot arm. (b) Flow mapping.

Fig. 2 Integrated arm robot and ultrasonic system.

3. Conclusion

The main feature of this study is that we proposed to combine the ultrasonic measurement with robot system. Therefore, the study represents a significant step forward in our ability to decommission the Fukushima Dai-ichi NPP.

References

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