Design and Simulation of Automated Accident Response Robot for Rapid Leak-Sealing with Self-traveling Capability

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1. Introduction

In areas such as safety and accident prevention, various studies have been conducted for ensuring rapid response capabilities in the early stage of the accident. Particularly in the case of nuclear-related accidents, the leakage of radioactive material and contamination can be severe. In this study, nuclear accidents where issues like pipe damages [1,2] can result in the leakage of radioactive materials are considered and the automated device previously designed [3] to seal the damaged pipes automatically is updated with more features such as traveling and locating itself on the pipe while the main task is undergoing.

2. Model Updates and Features

In the previous study, we proposed a rapid leak-sealing robot which can be carried and installed by other accident response mobile robot. We designed an early concept model with essential functions for leak sealing task, and as depicted in Fig. 1, where we proved the concept with a working model through a number of feasibility tests [3].

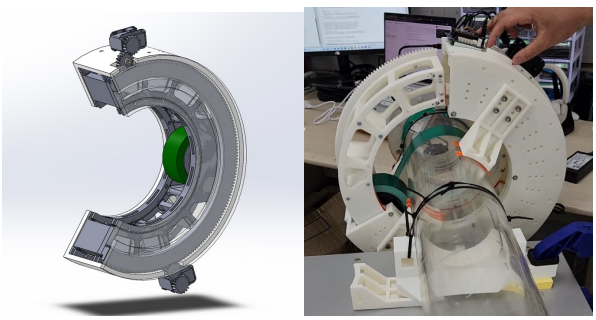


Fig. 1. Concept design and feasibility test in our previous study

As a result, rapid taping task on a damaged pipe could be successfully performed if the solid installation of the device on the pipe is provided. In this phase of the study, we're considering more realistic situation which requires additional features for solid installation and moving the device along pipe's outer surface. So, a little simplified but feature rich simulation environment to show the full feature feasibility of this rapid leak-sealing device is established.

To include physical operations required for additional tasks, we considered following features to help the device concretely perform the leak-sealing tasks to cover a wide range of pipe's leakage.

<List of additional features>
- Automatic alignment feature
- Movement feature on the pipe
- Tape attachment on the pipe
- Tape cutting and retrieval feature

Including above mentioned feature set, mechanisms are designed and the model of the device is updated like in Fig. 2.

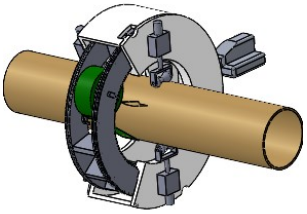


Fig. 2. Updated rapid leak-sealing robot model

The automatic alignment feature includes two or three linearly actuated elements which can adjust the radial position of the aligning roller to adapt to the diameter of the pipe to work with. The movement feature can make the device slide along pipe's length axis bidirectionally, and which provide we can adjust the starting and end location of the piping task. This also means the device is applicable to wide or narrow leak sealing range.

Since the device is fully automated once it is installed, attaching the beginning end of the tape on the pipe also need to be handled by the tape attachment element. While when it finishes the taping task for the specified area, it needs to cut the tape and retrieve it. Additionally, it also needs to have a handle to be carried and installed by a mobile robot, like depicted in Fig. 3.

Considering all these additional features, the simple model is updated and applied in the simulation environment to check the feasibility.

3. Simulation Study

Fig. 4 shows the simulation result of the leak sealing task completed by the proposed device. The first feasibility study employing the updated leak sealing device showed desirable results in a number of

simulation environment and the thickness of the taping was realized by adjusting the lateral movement speed of the device. This need to be determined more precisely later through a number of physical experiments simulating the leaking pressure from the damaged pipe.

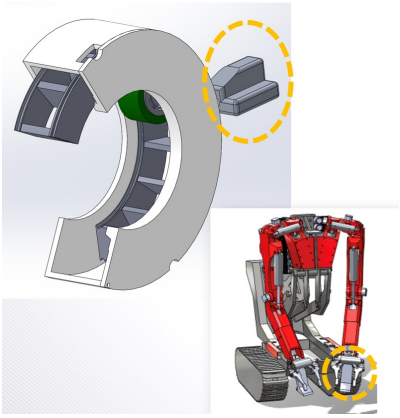
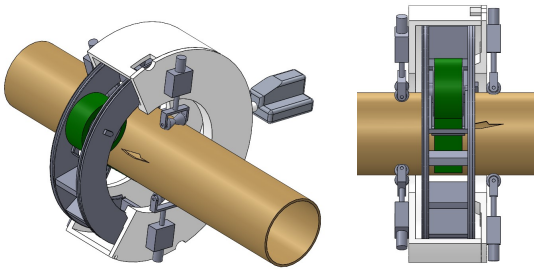
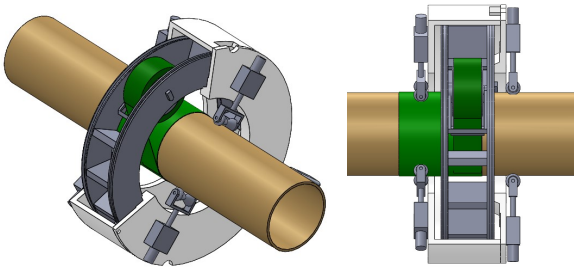


Fig. 3. Accident response mobile robot to carry the automated leak sealing device



(a) Begin phase



(b) Taping task completed

Fig. 4. Simulated feasibility study for the leak sealing task

4. Conclusion

Features added version of the automated leak sealing device was introduced in this study. The additional features modeled conceptually in this version was employed for feasibility studies in simulated environments and it showed reasonable taping performance for various range of damaged area. As a future study we will focus on the detailed design of the device to build a full-featured working model and prove the concept.

ACKNOWLEGEMENT

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