An approach to evaluate the cutting time for the nuclear dismantling simulation

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1. Introduction

Nuclear power plant (NPP) decommissioning involves various processes and technologies. Decommissioning should be performed after a comprehensive review of the information related to these processes and technologies. There are various means of prior examination and evaluation to ensure the feasibility and safety of the decommissioning process plan. Our dismantling simulation system aims to simulate and evaluate whole processes related to the dismantlement of core equipment of NPP such as the device preparation, cutting operation, waste transfer, and so on. This paper introduces the estimation methodology of the time required for the cutting processes based on real cutting conditions in order to provide effective economic evaluation functionalities used for the system.

2. Methods and Results

In this section, the introduction of the dismantling simulation system and the methodology used to evaluate the time required cutting processes in the simulation system are described.

2.1 Nuclear dismantling simulation system

Developed dismantling simulation system focuses on the design and evaluation of the dismantling processes of highly radioactive core equipment in a NPP. This dismantling simulation system was developed using the CAD application programming interface (API) based on commercial digital manufacturing software and virtual reality (VR) technologies [1]. Through these technologies the dismantling simulation system can provide users with an enhanced 3-dimensional real-time graphical simulation and also physical simulation functionalities [2]. In particular users can evaluate and manage the 3-dimensional physical properties, such as mass, volume, center of gravity and so on by the physical simulation based on solid modeling used for a CAD-based simulation system. Therefore, the economic evaluation functionalities based on physical properties like the management of secondary radioactive waste information during the dismantling of nuclear facilities can be applicable to the simulation system. Fig. 1 shows the user environment of the dismantling simulation system and the examples of launch screen.

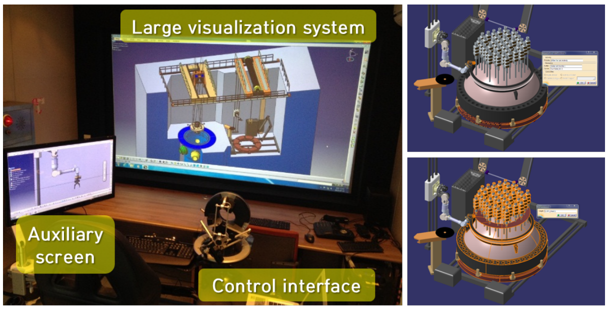

Fig. 1. The user environment of the dismantling simulation system and the launch screens

2.2 The methodology to estimate the time required for the cutting processes in the dismantling simulation

The economic evaluation factors which affect the remote dismantling simulation are very diverse. Among them, the time required for cutting processes is representative one. If reasonable estimation of the cutting time is possible, the dismantling simulation system can perform the basic economic evaluation for the remote cutting processes. The time required for the cutting process is depend on the cutting speed and its trace. The cutting trace can be exactly obtained by simulating the process in the system according to the remote dismantling scenario [3]. However, the cutting speed have to be calculated for each cutting condition of the processes. The cutting speed depends on the kind of the cutting device and the thickness of the target to be cut. Generally, the manufacturer of the cutting device provides discrete values of the cutting speed according to the thickness of the target. However, the dismantling simulation needs continuous cutting speed during the process simulation in real-time. So, in order to estimate the continuous cutting speed for the dismantling simulation system, we applied the third order spline fitting using the constraint condition. Fig. 2 and Fig. 3 is the results for continuous cutting speed which this estimation methodology applied to the mechanical cutting method using band-saw and the thermal cutting method using oxygen-propane gas. The reference data of the Fig. 2 and Fig. 3 were come from the manufacturer's whitepaper. We observed that the error between the reference data and spline fitting curve were less than 10%. When greater order of the spline fitting was used, the estimation curve followed exactly the reference data, but the result became unnatural.

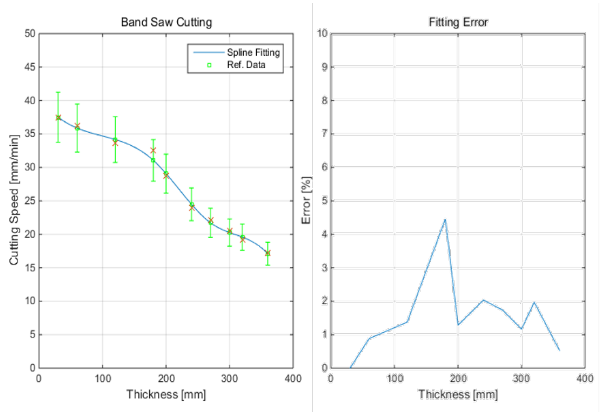

Fig. 2. The result of the estimation of the cutting speed using band-saw

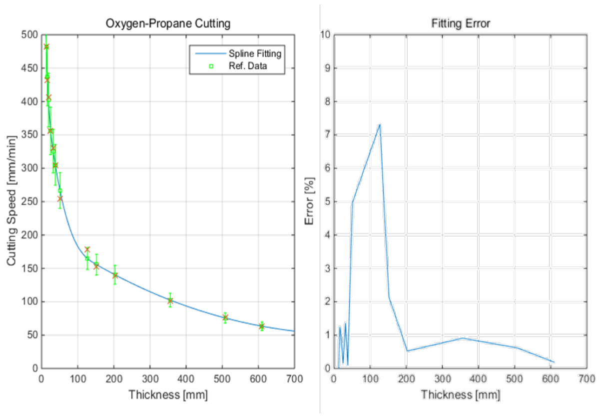

Fig. 3. The result of the estimation of the cutting speed using oxygen-propane gas

2.3 Verification of the estimation for the cutting speed through the cutting experiments

We verified the methodology for the estimation of cutting speed by the experiments. Result data for the cutting speed were obtained from image processing using the marker. Fig. 4 is the sample images at 30 seconds intervals to analyze the real cutting speed of the band-saw for a 400mm thick specimen.

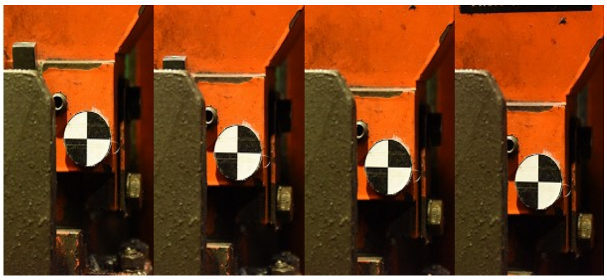

Fig. 4. The experiment to verify the estimation of the cutting speed using the band-saw

Fig. 5 is the experimental images at 5 seconds intervals to verify the cutting speed using oxygen-propane gas for a 150mm thick specimen. The specimen for both cases was carbon steel, SA-508 Gr.1.

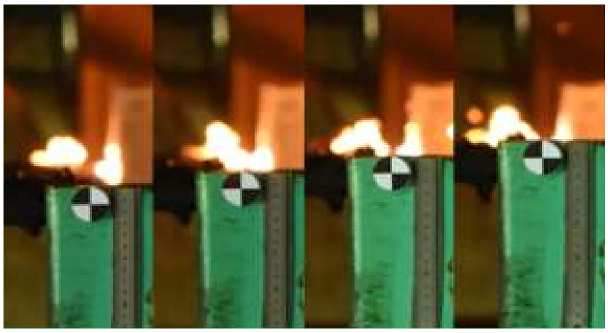

Fig. 5. The experiment to verify the estimation of the cutting speed using the oxygen-propane gas

Fig. 6 is the experimental results. We observed that the error between the experimental results and the estimation curve was 3.33% in case of the band-saw cutting, and 4.87% for the oxygen-propane gas cutting.

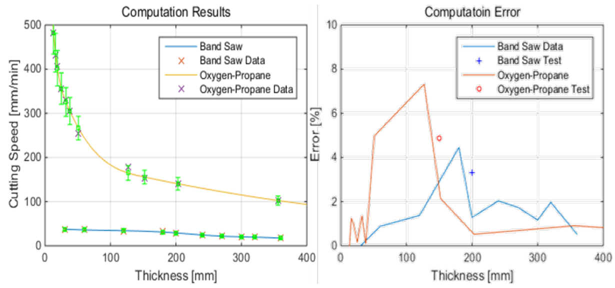

Fig. 6. The experiment to verify the estimation of the cutting speed using the oxygen-propane gas

3. Conclusions

The methodology to estimate the time required for the remote cutting process in the nuclear dismantling simulation system was proposed. Among the factors which mainly determine the time, the cutting trace was directly calculated from the simulation system and the continuous cutting speed was obtained by proper order of the spline fitting with constraint conditions. Through the verification experiments, we concluded that the estimation methodology to obtain continuous cutting speed for the dismantling simulation system was acceptable. The proposed approach is expected to provide effective economic evaluation framework used for the nuclear dismantling simulation system.

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