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An Impact Stress Estimation Technique using Impulse Response Signal of Acceleration

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1. Introduction

The primary system of nuclear power plant and research facilities (HANARO: Hi-flux Advanced Neutron Application Reactor) transfers heat energy generated from the nuclear reactor through a coolant pump to generate steam or cool it. When a metallic object is present inside the reactor, an impact occurs on the pressure vessel, piping, pump casing, etc. due to the flowing fluid and then it could cause a damage depending on the amount of impact energy.

In nuclear power plants, a Loose Part Monitoring System (LPMS) is installed and operated to monitor and diagnose such metallic objects [1,2].

When an impact occurs due to such metallic objects, the system first discriminates whether it is true or false signals, and information on the impact source is diagnosed by estimating the impact location [3,4] and mass. And then, based on this information, the impact damage assessment is analyzed at the impact location [1].

Conventionally, the assessment is performed based on the personnel experience of the expert. If there exists a possibility of damage, the operation must be shut down and maintenance must be carried out. In this occasion, the shutdown procedure requires a lot of time for operators to make a final decision. To reduce the time required, it is necessary to add the impact stress estimation to the monitoring system on an online basis.

In this paper, we have developed a technique to calculate the impact stress online by applying Hertz theory based on the estimated impact location, mass, and impact energy information.

2. Methods and Results

2.1 Impact stress estimation method

When an impact of metallic objects occurs within a pressure boundary structure, it is necessary to quickly diagnose the structural health status due to the impact. And the rapid decision making is highly required in order to meet the regulation procedure that requires making a decision within 72 hours from the initial detection of the loose part signal. Therefore, a numerical analysis-based impact stress calculation method for real-time processing is developed.

For this purpose, the loading conditions, and Hertz contact theory are applied to calculate the stress distribution based on numerical analysis (Asymptotic Method). The estimated stress results are compared with the allowable stress based on the Von-mises stress shear strain-energy criterion, Tresca's maximum shear stress criterion, and Maximum reduced stress criterion to diagnose the effect on damage to the plate structure.

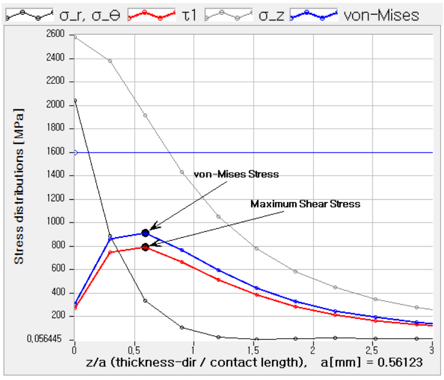


Fig. 1. Stress diagram results through numerical analysis

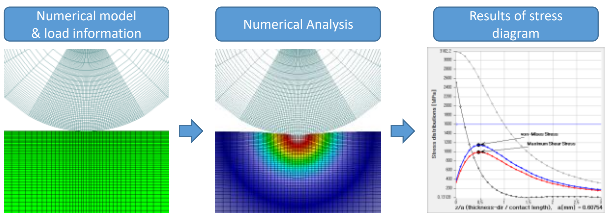


Fig. 2. Numerical analysis procedure for impact stress estimation

2.2 Finite element analysis

To verify the impact stress estimation method, the other impact analysis is performed using a commercial finite element analysis code. The impact target is a hemispherical shell structure with a radius of 534 mm, and the impact object is assumed to be a steel ball. The load conditions of the steel ball of 112 grams and the impact velocity of 0.6 m/s are applied. The analysis resulted in the impact stress distribution in the thickness direction based on the stress distribution of the impact cross section and the contact surface of the steel ball.

2.3 Comparison of the two analyses

In order to verify the numerical analysis-based impact stress estimation method proposed in this study, calculations are performed using the proposed impact stress estimation method and finite element analysis method based on the same load and boundary conditions as shown in Tables I and II.

Additionally, in order to compare the two results, the stress distribution in the thickness direction (z direction) of the plate is also calculated. Fig.3 and Fig.4 show that the two stress distributions are similar each other. Thus, it is implicated that the direct numerical method of the impact stress distribution will be possible to perform the damage effect assessment on an online basis.

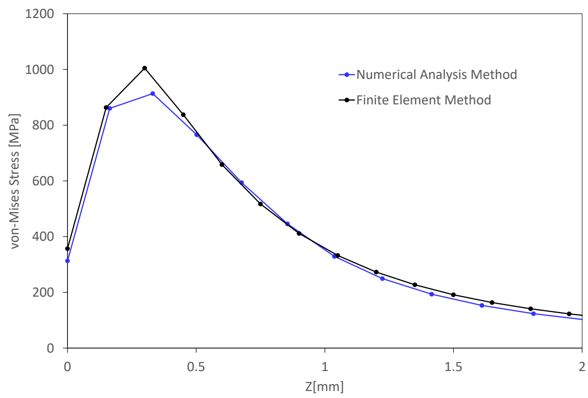
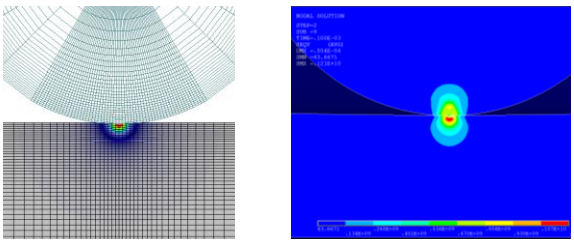


Fig. 3. Comparison of stress diagrams between numerical analysis ~~results~~ and finite element analysis results.



(a) Numerical method (b) Finite element method

Fig. 4. Comparison of stress distribution between numerical analysis ~~results~~ and finite element analysis results

Table I: Material Property Description

Property	Structure Plate	Impact Ball
Young's [GPa]	200	200
Poisson's Ratio	0.29	7800
Density[kg/m^3]	7800	0.29
Thickness[mm]	31.75	-
Yield Stress [MPa]	320	-

Table II: Boundary & Load Condition Description

Analysis Condition	Value
Ball Mass[gram]	112
Impact Velocity[m/s]	0.6
Ball Radius[mm]	15.1

3. Conclusions

A technique to estimate the impact stress on an online basis was developed using the numerical analysis based on Hertz contact theory based on the impact location, impact mass, and velocity information. And the estimated stress was applied to analyze the degree of damage by comparing it with the allowable stress. To verify the proposed method, a finite element analysis was implemented, and the results were compared and verified. Thus, it was found that the online basis impact stress estimation could be applied to diagnose the effect of impact.

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