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Simulation of a Local Collision of SC Wall Using High Energy Absorbing Steel

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1. Introduction

Local damage evaluations for nuclear power plant(NPP) design are performed against turbine impact, tornado impact, airplane engine impact, etc., where turbine is a internal source of impact, whereas tornado and airplane engine are external sources of impact. The thickness of NPP wall structure is determined at initial design stage not to be penetrated by local impacts. This study investigated the local damage of NPP sub-structure against internal turbine impact. Simulation of local collisions of SC wall in NPP structure, which consists of two models: one using general steel and the other using high energy absorbing steel, were performed. The performance of SC wall using ductile high energy absorbing steel can be greatly improved on local collisions when compared with that of general steel.

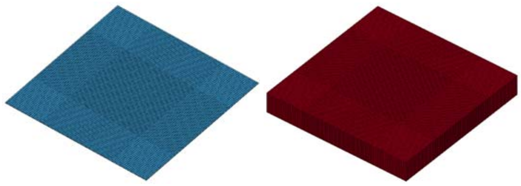
2. Numerical Simulation of Collision

A SC structure used in this analysis has thickness of 5ft(1524mm), which consists of 58.5in(1485mm) concrete wall and two 0.75in(19.05mm) steel plates. The plane shape of SC structure is a 9000mm by 9000mm square. Two steel plates protect concrete wall at both sides and the behavior of SC structure is analyzed when the turbine collides with internal steel plate. The analysis is done using LS-DYNA[1] and the turbine model[2] of previous simulation is adopted.

2.1 Finite Element Model

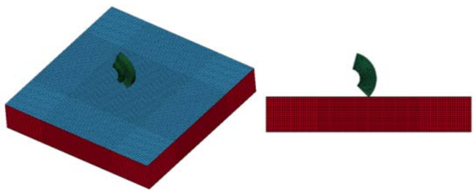
The concrete part of SC structure target is modeled as 8 node solids and steel liner is described as fully attached 8 node solids (Fig. 1). The concrete target is part of wall structure such that the boundary of wall structure is modeled as a fixed end. The center part of SC structure, where impact occurs, is finely discretised and the rest parts are meshed more coarsely for efficiency. When the SC structure is hit by the impact of turbine, nodes of each structure have contacts and they needs to be defined properly during the finite element analysis. Shapes of the system at the instant of collision are described in Fig. 2.

The shape of turbine impact structure is determined based on the result in [2]. Details of impact structure are shown in Fig. 3(b), which was produced by the rotation of the cross section in Fig. 3(a) in the amount of $\frac{2}{3}\pi$ radian.



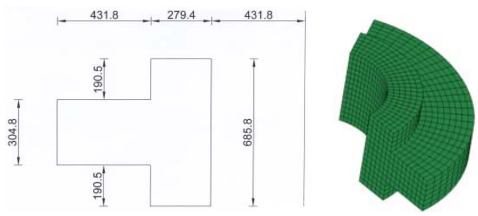
(a) steel plate (b) concrete

Fig. 1. Finite element models of SC wall structure



(a) shape of total system (b) shape of cross section

Fig. 2. System shapes at the instant of collision.



(a) Cross section dimension (b) Finite element shape

Fig. 3. Turbine impact structure

2.2 Material Model

LS-DYNA has 3 nonlinear concrete models, with compressive strength of concrete, tensile strength of concrete, elastic modulus, and poisson's ratio as parameters. The study in [3] compared three material models by analyzing previous test results and made conclusion that the CSCM(Continuous Surface Cap Model) concrete is best suited to the test results. Based on this result in [3], CSCM concrete is applied to the local collision analysis in this study. According to the fact that the impact structure hit the SC structure (compressive strength = $59.85MP$) at the speed of $128.016m/sec$, strength increase due to the increase of strain velocity is implemented.

Steel plate and impact structure are modeled using *Plastic Kinematic* material and three kinds of steel plates made of ASTM A36, ASTM A496, and High

Manganese Steel(High Energy Absorbing Steel) in Table 1 are applied for local collision analyses. Turbine impact structure is made of ASTM A36 with the mass of $3764.8kg$ and it hits the SC wall at the right angle in Fig.2. The stress-strain curves of applied steel models are presented in Fig. 4. The yield stress of high manganese steel is between those of A36 and A496 and the ductility of high manganese steel is superior to other steel models.

Table 1. Material characteristics of steel models

Property	ASTM A36	ASTM A496	High Manganese Steel
Density (MPa)	0.00785	0.00785	0.00785
Modulus of Elasticity (MPa)	199948	199948	199948
Poisson's Ratio	0.3	0.3	0.3
Yield Stress (MPa)	248.2	482.6	401.0
Ultimate Strength (MPa)	400.0	551.6	1076.0
Failure Strain	0.15	0.08	0.67

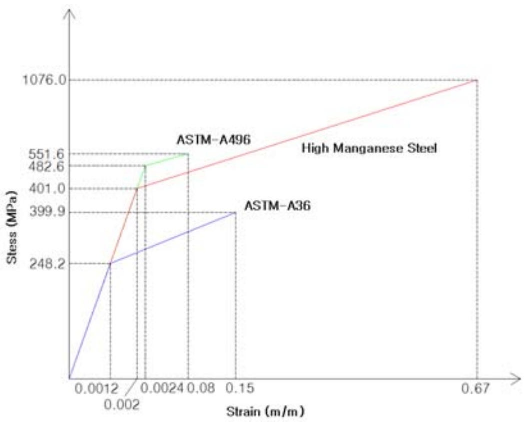
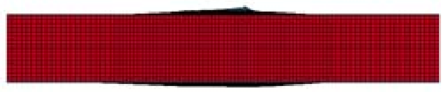


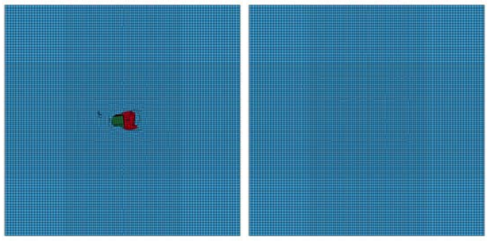
Fig. 4. Stress-strain curves of steel models

3. Results and Conclusions

Analysis results show that the penetration of steel plate after the collision occurred in cases of A36 and A496 steel plates. The SC structure with high manganese steel plates was not penetrated, though the impact structure advanced up to $110mm$ deep(Fig. 5). Therefore, the ductile high energy absorbing steel plate can be applied to SC wall structure to improve the resistance level against local impact loads more efficiently.



(a) cross section



(b) collision surface (c) back surface

Fig. 5. Shape of local damage in case of high manganese steel plate.

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