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Analyzing the effects of size of hole on Plate failure

Behzad Mohammadzadeh[a], Hyuk Chun, Noh[b]*
[a]*Ph.D Student, Dept. of Civil Engineering, Sejong University, Gwangin-gu, Seoul*
[b]*Associate Professor, Dept. of Civil Engineering, Sejong University, Gwangin-gu, Seoul*
Corresponding author: cpebach@sejong.ac.kr

1. Introduction

Plates are popularly used in constructing various parts of nuclear power plants[3] and other structures. According to requirements, it is occasionally required to make hole in plates used in some parts such as piping systems(cooling system), electrical cables path, or use for some linkage to flange or web, and so on [1].In central part of nuclear power plant (Reactor), the reactor core's heat is generated by controlled nuclear fission. With this heat, a coolant is heated as it is pumped through the reactor and thereby removes the energy from the reactor. For the purpose of heat transfer from the nuclear power plant core, the water is circulated continuously in a closed loop steam cycle pipeline [7]. In the event of an emergency, some considerations are required to prevent pipes from bursting or the reactor from exploding. A form of sudden failure occurred to a structural member is buckling which happens in case of subjecting high compressive stress [6].

The load at critical point in which an infinitesimal increase in load can make the plate to buckle, is buckling load [2]. When a plate element is subjected to direct compression, bending, shear, or a combination of these stresses in its plane, the plate may buckle locally before the member as a whole becomes unstable or before the yield stress of the material is reached. Holes can either increase or decrease critical load of a plate depending on its position and geometry[5].The presence of holes in plates will change the strength and stiffness, so the amounts of stress and its distribution which induce strain and buckling will be changed [4].This study deals with studying the buckling of plate with holes using finite element method(FEM).

2. Methods and Results

In order to analyze the plate, software ABAQUS is employed. Plates with different size of hole with constant dimension of X=0.2m (Long side) and Y=0.1m (Short side) are considered to be simulated. Because we are investigating the effect of hole-diameter (hole size) on buckling of the plate with hole, the boundary condition is assumed not to change. The left edge is constrained in all directions but the other edges are supported only for Z direction(Direction 3).Materials of plate is considered to be steel with modulus of elasticity E=209E09 and Poisson's ratio υ=0.3. The thickness of plate is considered to be constant and equal to 10mm. A constant and distributed load is applied on the right edge of the plate with magnitude of 1N/m for all the specimens. Not only because plates are used extensively in the nuclear power plants but also they are multifunctional structural elements, we consider the plates have two holes. Center of the holes are considered to be placed on the plate at position of X=0.05cm and Y=0.0cmandX=-0.05cm and Y=0.0cm for right hole and left hole respectively. Firstly, the plate having holes with diameter of 1cm is analyzed, and then the diameters of the holes are increased by 1cm in the following analyses. The size of the diameter increases up to 7cm. Based on linear buckling analyses, we suggest critical loads for the first three modes, as given inTable1. Fig. 1 shows the deformed shape of the plate for mode 1.

Table 1: Critical Loads for different size of holes

NO	Diameter (m)	Critical load (kN/m)		
		Mode I	Mode II	Mode III
1	0.01	8,622.00	10,318.50	14,108.70
2	0.02	8,067.56	9,926.54	14,303.90
3	0.03	7,659.87	9,509.87	13,995.30
4	0.04	7,528.22	9,306.91	13,453.50
5	0.05	7,371.52	9,499.80	12,714.90
6	0.06	6,913.31	10,575.40	110,112.60
7	0.07	6,203.65	9,079.88	11,060.50

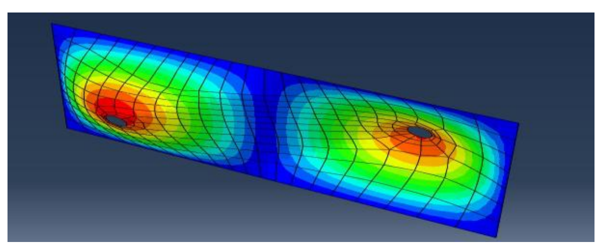

Fig. 1. Mode 1 of deformed plate

As can be seen from table 1, by increasing the size of holes the amount of buckling load (Critical load) is decreased. The maximum magnitude of buckling load corresponds to the smallest hole as expected and the biggest hole resulted in the smallest critical load. As observed from table 1, the differences between critical loads do not show a regular variation as the diameters are changed regularly. So it is required to investigate that in what range of changing in the diameter of the holes the maximum change in buckling load is occurred. Fig. 2 shows the differences between critical load VS different diameter of holes.

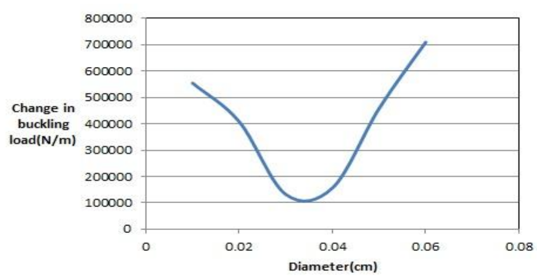

Fig. 2.Irregular Change in magnitude in buckling load following the change in hole-diameter.

Buckling load changes by changing the diameter of a hole. In order to have better investigation on buckling load of plate with holes we need to consider a relationship between size of the hole and the size of the plate [4]. By increasing the hole size, decrease in effective length of width of plate, a-D, is greater than that of length of plate, b-D. So the ratio D/a is used to show the relationship between hole size and critical dimension of the plate, and named as “dimension ratio”. Fig. 3 shows the buckling load against D/a ratio describing what is the trend of plate with different D/a. Also it can give information on which size of hole can be used to sustain a specific buckling load.

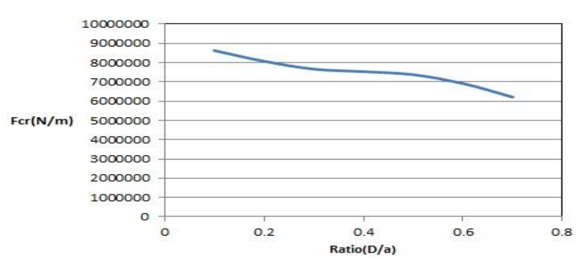

Fig. 3. Critical load versus dimension ratio (D/a)

As it can be inferred from the graph shown in Fig. 3, the general trend is decreasing. For D/a ratio from 0.1 to 0.3 the amounts of buckling load decreased similarly for those from 0.5 to 0.7 but with inverse concavity which states that by the increase in D/a ratio from 0.5 to 0.7 the rate of decreasing in critical load, which shows the resistance of plate against buckling, is much faster than the other ranges. Trend of graph for range from 0.3 to 0.5 is virtually plateau demonstrating that critical load is not affected by the varying value of D/a in this range. This means that the grater hole can be used without decreasing the buckling load.

3. Conclusions

Buckling is one of the main reasons for steel members to fail during service life time. As plates are frequently used in the structures of nuclear power plants and in some cases making holes in plates is necessary, it is necessary to assay the capacity of the plates especially in terms of buckling. FEM is a useful approach which makes the plate analysis be performed with ease. This study relates the buckling load of plates with through-thickness holes to a dimensionless parameter (D/a). By increasing D/a ratio, the amount of plate strength is observed to be decreased. After D/a=0.5, the rate of decreasing is observed to be increased drastically. Therefore, it is better to use ratio D/a less than or equal to 0.5. As a further study, it is possible to investigate other aspects such as different thickness, different positions and so on.

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