11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

SHAPE OPTIMIZATION OF SHEAR PANEL DAMPER CONSIDERING PLASTIC ENERGY DISSIPATION

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Key Words: *Shape Optimization, Shear Panel Damper, Finite Element Analysis.*

Shear panel dampers as shown in Fig. 1 are widely used for seismic response reduction of building frames utilizing plastic energy dissipation in the steel panel. Some openings are placed to dissipate energy in wide region of the panel, and to alleviate stress concentration that leads to premature fracture. Energy dissipation property can also be improved by optimizing the boundary shape [1]. The authors developed a method for optimizing locations and thicknesses of the stiffeners [2]. In this study, we present an optimization result of the shape and locations of the openings of a steel shear panel damper.

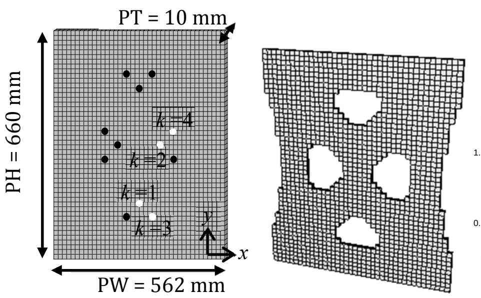


Fig. 1. Geometry and topology of a shear panel damper.

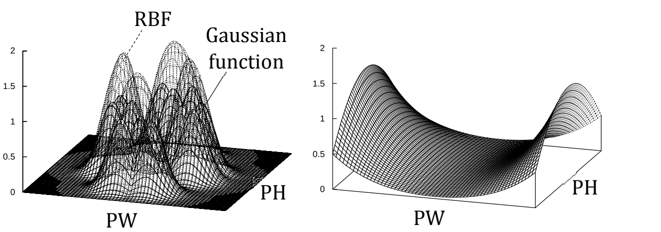


Fig. 2. Gaussian functions and Bézier surface

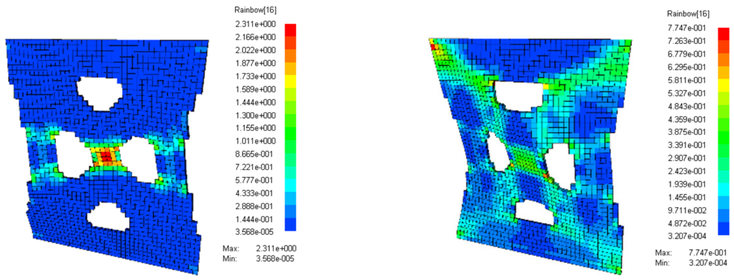
Consider a shear panel damper model as shown in Fig. 1 with thickness 10 mm and four openings. The material of panel is steel, where Young's modulus E is 200 GPa, Poisson's ratio is 0.3, and coefficient of kinematic hardening is 0.005 E. The finite element analysis software package ADVENTURECluster [3] is used for cyclic static elastoplastic analysis. A linear hexahedral element is used. The number of elements is $40\times48\times2$ = 3840, and the number of DOFs is 17343.

The shape of each opening is defined by a level set function as the summation of 12 Gaussian radial basis functions $h_k(x,y)$ and a 5×5 tensor product Bézier surface $P(x,y)$. Let x_k, y_k, r_k, and w_k denote the x, y coordinates, size parameter, and weight of the kth radial basis function. The level set function $Q(x,y)$, defined as follows, is evaluated at the center of each element, and the element is removed if $Q(x,y)>0.5$:

$$\hat{z}(x,y)=\sum_{k=1}^{12} w_k h_k(x,y), \quad h_k(x,y)=\exp\left(-\frac{(x-x_k)^2+(y-y_k)^2}{2r_k^2}\right) \tag{1}$$

$$Q(x,y)=\frac{P(x,y)+\hat{z}(x,y)}{\left(P(x,y)+\hat{z}(x,y)\right)_{\max}} \tag{2}$$

where the subscript 'max' means the maximum value for normalization of $Q(x,y)$.



(a) initial model (b) optimal model

Fig. 3. Distribution of equivalent plastic strain.

Optimization is carried out using a local random search. The variables are x_2, x_3, x_4, y_1, y_3, y_4, r_1, and r_2 of the openings defined in Fig. 1, i.e., the number of variables is 8. Note that the parameters for Bézier surface is fixed to keep the boundary shape almost constant. Cyclic forced deformation of shear angle 1/60 is assigned under constant vertical strain of 1/2000. For the initial model in Fig. 3(a), the dissipated energy is $E_{\mathrm{p}}=28.2$ kNm, the maximum horizontal reaction is $R_{\max}=390.1$ kN, and the maximum equivalent plastic strain among all elements is $\varepsilon_{\max}=0.741$.

The objective function for optimization is the value of E_{p} until $\varepsilon_{\max}$ reaches 0.741. The optimal shape is shown in Fig. 2, where $E_{\mathrm{p}}=92.0$ kNm, $R_{\max}=441.5$ kN, and $\varepsilon_{\max}$ reaches 0.741 at the end of the 3rd cycle. This way, the shape of opening of a shear panel damper can be effectively optimize to enhance energy dissipation capacity by increasing the number of cycles to reach the specified value of maximum equivalent plastic strain.

• This work was supported by JSPS KAKENHI Grant Number 23360248 of JSPS, Japan

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