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MULTI-OBJECTIVE SHAPE OPTIMIZATION OF STEEL SHEAR PANEL DAMPERS

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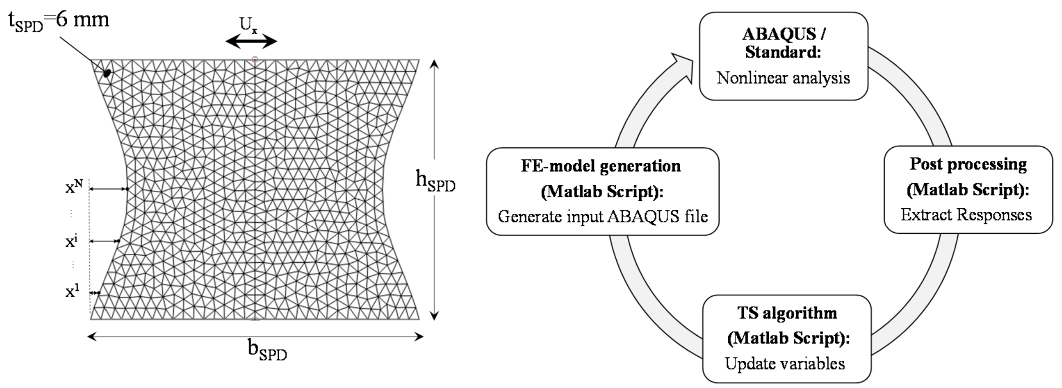
Shear panel dampers (SPDs) have stable energy dissipation capacity as well as low material and fabrication cost (Deng et al., 2015). Along with the recent evolutions in computer technology and numerical analysis methods, the implementation of optimization algorithms in a wide range of engineering mechanics problems is substantially increased.

Hedayat (2015) employed optimization algorithms and finite element updating methods to improve the cyclic behavior of slit dampers. Liu and Shimoda (2013) implemented shape response surface method (RSM) to improve plastic strain distribution of SPDs under cyclic loading. The edges of samples were assumed to be parabolic and the optimal parameters for the parabola were obtained using regression analysis. The results showed that edge shape optimization can be considered an effective approach to improve the cyclic performance of SPDs.

Tabu Search (TS) optimization approach is used in this study. According to Figure 1-a, the horizontal location of N equally spaced control points on the side edges of SPD are considered as independent design variables to acquire the optimal shape of the energy dissipation device. The free boundaries on the sides of the plate pass through all the control points with straight lines between every two adjacent points. In spite of studies mentioned before, two objective functions are considered in this study: Maximizing the energy dissipated by the inelastic deformation of SPD model, E(X), and the number of tolerated cycles N^f (X) before the maximum equivalent plastic strain (PEEQ) among the entire plate reaches the value corresponding to failure of SPD model ($PEEQ^{max}$).



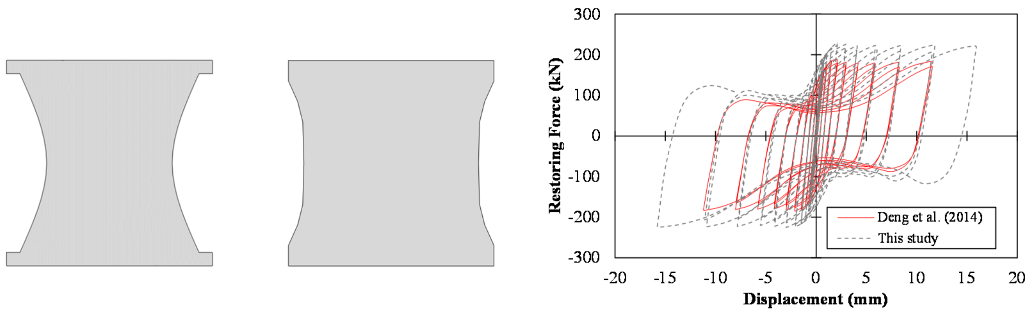
(a) (b)

Figure 1. (a) SPD geometrical optimization variables and mesh density of the finite element model, (b) The workflow between the TS algorithm and FE analysis software, ABAQUS.

Initial geometric imperfections were incorporated in the numerical models to mobilize the buckling response of the yielding plates. The most critical buckling shape is commonly recognized as the most conservative initial geometric imperfection distribution (Kiani et al., 2015). The maximum amplitude of the initial imperfection is assumed to be equal to one percent of the height of SPD models. Therefore, an eigenvalue buckling analysis under pure shear stress has been carried out for each SPD model and the first eigen mode has been considered as the pattern of the geometric imperfection. S3R shell element (triangular) with reduced integration and linear interpolation used for modeling. All translational and rotational degrees of freedom except lateral translation (in the X direction) at the loaded end were restrained as is shown in Figure 1-a. The workflow between the TS algorithm and FE analysis software, ABAQUS is also shown in Figure 1-b.

Deng et al. (2014) used simulated annealing (SA) method to optimize the shape of four SPD models with different aspect ratios. The optimized shape for an SPD with height and width equal to 400 mm and thickness of 6 mm which were optimized by Deng et al. (2014), were optimized again with the algorithm discussed in this study. The shape of SPD proposed by Deng et al. (2014) and the optimized shape obtained in this study are compared in Figures 2-a and 2-b respectively. The cyclic responses of both models are also compared in Figure 2-c. As is shown, the restoring force, maximum tolerated shear deformation and consequently, the dissipated energy by the optimized model in this study are much higher than those of the proposed shape by Deng et al. (2014).

According to the results, the proposed TS optimization algorithm can be effectively used to improve both the dissipation capacity and low-cycle-fatigue resistance of SPD models.



(a) (b) (c)

Figure 2. (a) The Optimized shape proposed by Deng et al. (2014), (b) The optimized shape obtained in this study, (c) Comparison of the cyclic response of two SPD models.

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