Standard example: Integrated optimization of stiffened plate

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ABSTRACT
As a supplementary example, this paper further takes the beam and the plate as topological variables, and uses the second-order multi-point approximation method and topology judgment based on graph theory to solve the optimization problem of the stiffened plate. The results are as follows: the irrational individuals accounted for 16.8% in the total number of iterated individuals and get better structral mass.

1. Integrated optimization of stiffened plate

1.1. *Model description*

This is a standard example. As shown in the Figure 1, the length and width of the stiffened plate are 0.1m, and the thickness is 0.001m. The boundary conditions are fixed at four corner points. The material is stainless steel with young's modulus of 200GPa, poisson's ratio of 0.3 and density of the material is 7800kg/m^3. The cross-section of the stiffener is rectangular. The plate is loaded by a concentrated force in the center.

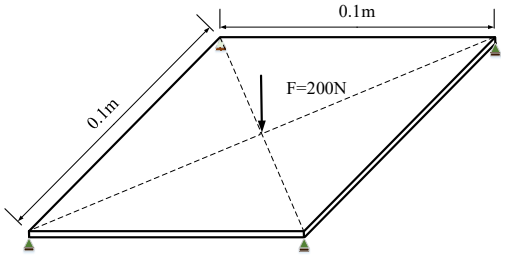

Figure 1. Stiffened plate model simulated by the beam element

Considering the symmetry of the structure, only one quarter of the structure of the plate is considered in the calculation, and the distribution and size of the remaining three quarters of plates and bars are obtained by variable chain technology. The objective function of the optimization problem is to minimize the structural mass. The constraint condition is that the maximum displacement of all structural nodes is not

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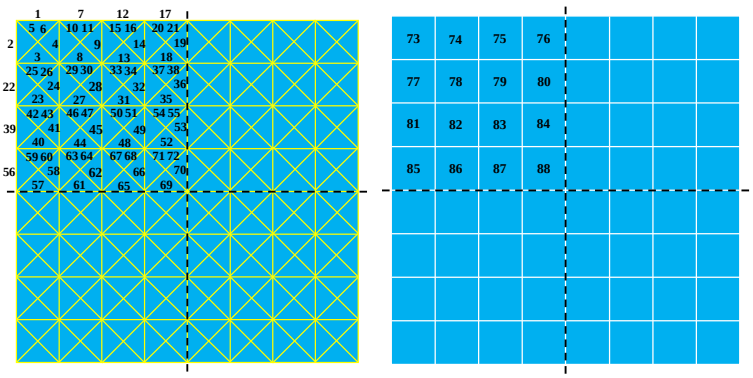
more than 0.5mm under the action of concentrated load and there are no manufacturing constraints. The design variables include 88 discrete variables, among which 72 represent the stiffeners and 16 represent the plates. Continuous variables are the width 'W' and height 'H' of the reinforcement(initial value is 4mm), the thickness 'T' of the plate (initial value is 1mm), and the designable range of 'W, H' and 'T' is 1∼4mm. The initial total mass of the structure is 0.585kg. The positions of discrete variables are shown in Figure 2.

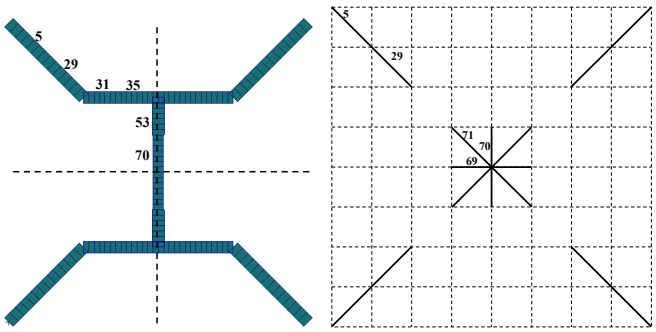


(a) Variables associated with beams (b) Variables associated with plates

Figure 2. Location and number of discrete variables

1.2. *Optimization results*

After the genetic algorithm gives the code of topological variables, the graph theory model and method established in this paper are used to judge the rationality of structural topology. If the structure is reasonable, the detail size is optimized; otherwise, the adaptive value is set to zero. The optimized topological configuration is shown in Figure 3 and all the plate variables are deleted. The detail dimensions corresponding to reserved discrete variables are shown in Table 1.



(a) Configuration in this work (b) Configuration in Ref.(Huang *et al.* 2018)

Figure 3. The comparison of optimized configurations

Comparing the changes of the total mass of the structure, the plate is also taken as a design variable to have more design space, which can reflect its important research significance. The iterative curves of objective functions and irrational topo-

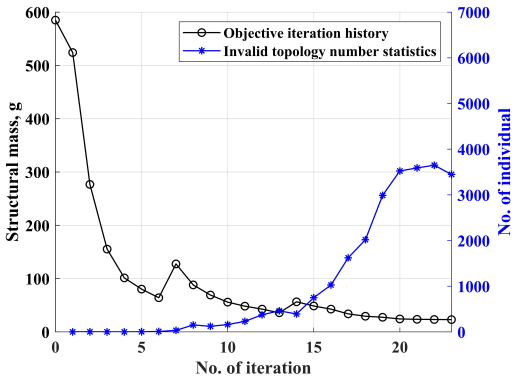


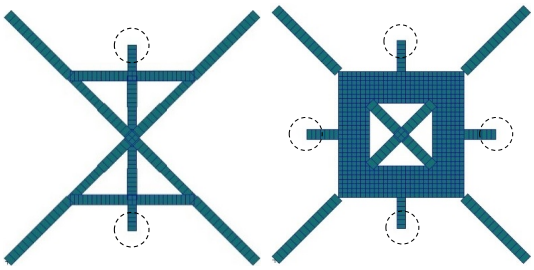
Figure 4. Iterative history of objective function and irrational topology individuals for Example 1

Table 1. Optimization results for Example 1.

		Topology and Sizing Optimization Results	
Variable number	**Property**	**This work/mm**	**In Ref.(Huang *et al.* 2018)/mm**
5	H	4.000	4.000
5	W	3.443	3.771
29	H	4.000	4.000
29	W	1.326	1.234
31	H	2.866	–
31	W	2.866	–
35	H	4.000	–
35	W	2.484	–
53	H	4.000	–
53	W	1.887	–
69	H	–	4.000
69	W	–	1.000
70	H	4.000	4.000
70	W	4.000	1.000
71	H	–	4.000
71	W	–	1.286
Total number of stifferens		20	16
Structral mass/kg		0.0231	0.0934
Max displacement/mm		0.5015	0.4998
No. of structural analysis		23	28

logical individuals are shown in Figure 4. The optimization process converged after 23 calculations, in which the effective weight loss is 0.5619kg, and irrational individuals accounted for 16.8% in the total number of iterated individuals. The maximum response displacement of the node is 0.5015mm($\approx$ 0.5mm), which satisfies the constraint conditions and is critical constraint.

Comparing the times of structural analysis, it is found that the times of structural analysis with plate as discrete variable is lower than that without plate as discrete variable. In the Ref.(Huang *et al.* 2018), such "suspended structures" are gradually eliminated through the global search ability of genetic algorithm, so the efficiency of the method based on graph theory is also reflected in the ability to directly exclude the existence of suspension points. The irrational configurations that can be effectively identified in the iteration process are shown in Figure 5, which cannot be excluded by the global stiffness matrix in the tradition. To sum up, the judgment method of topology rationality based on graph theory in this paper is effective.



(a) (b)

Figure 5. Configurations with non-base suspension points

References

Huang H, An HC, Ma Haibo, Chen SY. 2018. "An engineering method for complex structural optimization involving both size and topology design variables." *International Journal for Numerical Methods in Engineering*, 117(3):291-315.