

Highly Optimization Design of Structure Space

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Abstract. The optimization mathematical model for highly optimization is established with the constraints of strength, rigidity, stability and the structural deflection of structure space and solutions are obtained by using the genetic algorithm. A example indicates that the genetic algorithm can be applied in the optimal design of structure space and reliable results can be obtained.

Introduction

Space truss is a sort of extensive space structural form. The structure can be seen at oil service, stadium, large-scale dining room, marketplace, and so on. Its pole piece arranges according to the certain regulation, and it is a space net structure through the node conjunction. Many space trusses carry out structural function by steel structure. So, there is actual meaning with optimization to steel structure. According to 《the Space Trusses Design and Construction Rules》(JGJ7-91),this paper study optimization design of space truss structures with the genetic algorithm.

Built space trusses mathematical model

Mathematical model of optimization design is mathematical description to engineering problems optimization design, it has three basic elements: design variables, objective function and constraint condition.

Design variables

Regard Highly of Structure Space as design variables:

$$h = [a, b] \quad (1)$$

Which: h -- Highly of Structure Space ; a, b -- constants

Objective function

Objective function is total weight of space trusses' member bar

$$\min W(A) = \sum_{i=1}^n r_i g l_i \quad (2)$$

Which: $W(A)$ -- total weight of space trusses' member bar, kg

r_i --linear density of bar, kg/m; l_i --length of bar, m

n --total numbers of bar, g —acceleration of gravity, 9.8m/s^2

Constraint condition

Space trusses' member bar is axially loaded members. axially loaded members be control by strengthen and stiffness, axially loaded compression members be control by strengthen, stiffness and stability. So, constraint condition of Optimization Design of Structure Space is:

$$\left| \frac{N_i}{A_i} \right| \leq [\sigma] = 215 \text{ N/mm}^2 \quad (3)$$

$$\lambda = \frac{l_0}{i_i} \leq [\lambda] = \begin{cases} 180 \\ 300 \\ 400 \end{cases} \text{ Tension member of nearby bearing} \quad (4)$$

$$\left| \frac{N}{\varphi A_i} \right| \leq [\sigma] = 215 \text{ N/mm}^2 \quad (5)$$

$$A_i \geq A_{\min} \quad (6)$$

Which: N_i -- axial force of bar, N; A_i --sectional area of bar, m²; $[\sigma]$ --allowable stress of bar, N/mm²;

λ --slenderness ratio of bar; l_0 --effective length of bar, m; i_i --radius of gyration of bar, m;

$[\lambda]$ -- allowable slenderness ratio of bar; N -- axial force of compression bar, N; φ --stability coefficient axial compressive membe; A_{\min} --min sectional area of bar, m².

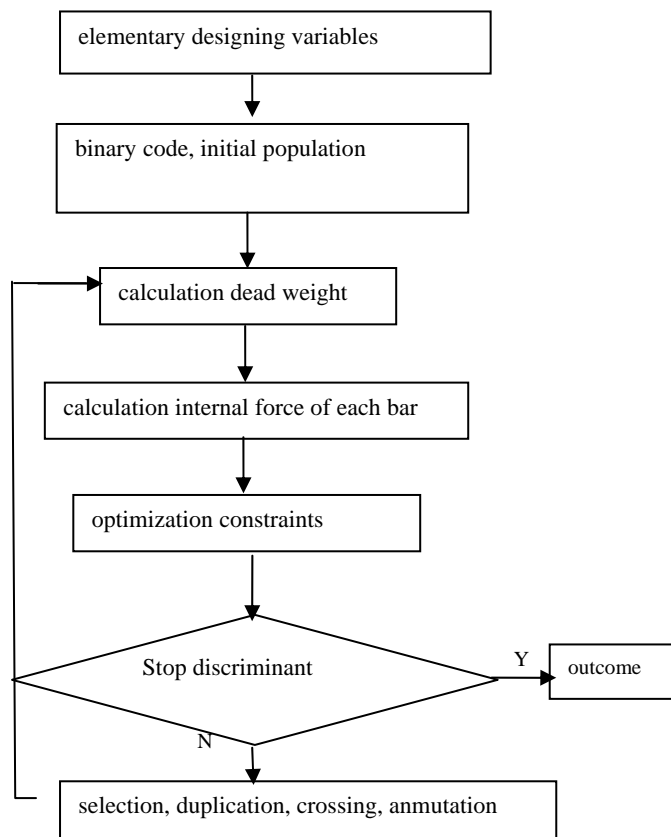


Fig 1 GA Process chart

Structure analysis

Structure Space must be mechanical analysis in the optimal procedure of the structures. This paper used space truss displacement method to calculation the internal force . This method consider joints in space truss three linear displacement as unknown quantity, suitable for all kinds of structure space, and considered different plane shape, different boundary conditions and supporting way, bear any loads and effect. The paper use space truss displacement method to calculate internal force of Structure Space the relation between elemental rod end force and nodal displacement in the whole coordinate:

$$\{F\}^e = [k]^e \cdot \{\delta\}^e \quad (7)$$

Whole stiffness equation can get by node equilibrium conditions and deformation compatibility condition.

$$P = K \cdot \delta \quad (8)$$

Supporting the introduction of boundary conditions, on the stiffness of the overall equation available structure of the node displacement vector can be obtained and then the structure of the unit under the axial force.

Description of genetic algorithm

The GA has a strong search capability in the large search space. Genetic Algorithms are search algorithms based on of natural evolution processing including selection, mutation and crossover operations on the genes of individuals or potential solutions.

GA is based on the principle of the theory of evolution developed a widely used and efficient method of random search and optimization. In engineering, computer science, management science and social science fields, in a very broad application.

Genetic algorithms, including the realization of the process of encoding, the initial group, fitness, choice of cross, the basic genetic mutation operation.

Fitness: According to the biological evolution "survival of the fittest" principle, the needs of each individual's ability to adapt to the environment compared in order to introduce the concept of fitness, fitness is the value of genetic algorithm in the evolution of groups used the only information it How to copy the string gives quantitative description. Fitness function by calculating the value of the individual's fitness, to compare the individual's fitness.

Genetic Operation: Genetic population operations for the individual to choose to copy the string, the crossover and mutation, and so on to deal with the aim of a new individual, constitute a new species. This process is the biological evolution of imitation. The overall population have a fitness than a generation ago, after several generations of iteration, the population has been continuously optimized, the process is similar to the natural world of biological evolution. Measure the fitness of individual parameters is the fitness function.

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The use of Matlab software program, developed a network to solve the structure of internal force and displacement of the finite element program, the preparation of three genetic operator, on this basis, the preparation of the grid structure of the genetic algorithm procedure, carried out a grid structure Design of optimization calculation. Figure 1 for the genetic algorithm flow chart

Examples and analysis of the results Conclusion

Simply supported around the pyramid is put grid, Grid size is 3.0m, Grid number is 11×11, Materials is Q235, Young's modulus is $E = 2.06 \times 10^5 \text{N/mm}^2$, Network load for the dead load standards is 30Kg/m^2 , Living standards set value is 50Kg/m^2 , optimize the results of the literature [1] results shown in Table 1.

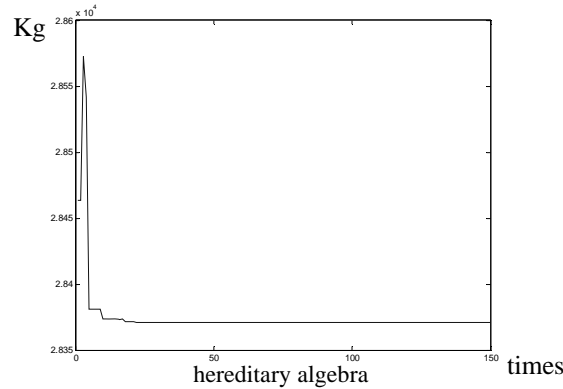


Fig 2 33m×33m optimization process
 Tab 1 33m×33m Highly optimized results comparative

	Mass(kg)	Height of space trusses(m)	Rise-to-span ratio
Before the optimization	32126	1.8	0.055
After the optimization	28371	1.7	0.052
optimum ratio	11.69%	5.5%	5.5%

Simply supported around the pyramid is put grid, Grid size is 3.0m, Grid number is 12×12, Materials is Q235, Young's modulus $E = 2.06 \times 10^5 \text{N/mm}^2$, Network load for the dead load standards is 30Kg/m², Living standards set value is 50 Kg/m², optimize the results of the literature [1] results shown in Table 2.

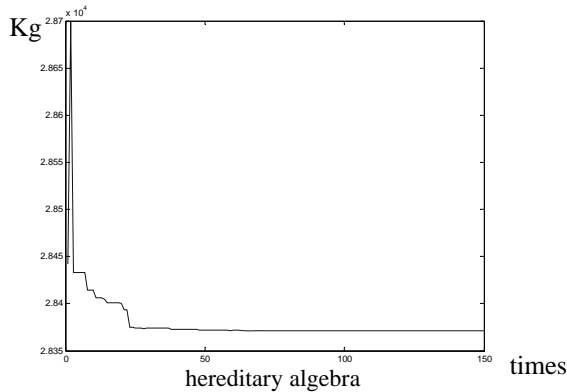


Fig 3 36m×36m optimization process
 Tab 2 36m×36m Highly optimized results comparative

	Mass(kg)	Height of space trusses(m)	Rise-to-span ratio
Before the optimization	33696	2.7	0.075
After the optimization	28398	2.5	0.069
optimum ratio	15.72%	7.41%	8.0%

Conclusion

- 1) Using genetic algorithms to solve the structure of a high degree of network optimization for different boundary conditions, support a different way, as well as to bear the load of different grid structure.
- 2) Using genetic algorithms to optimize network structure of high global optimization can be carried out to avoid the results of a local optimal solution;
- 3) Using genetic algorithms to optimize network structure height, to save steel, reliable and can be used in actual projects.

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