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OPTIMIZATION OF MULTISTORY STEEL FRAME MEMBERS USING GENETIC ALGORITHM

Abstract. This study presents the development and implementation of the genetic algorithm model in optimization of members of steel multistory frame. The developed model shows superior results when compared to the classical model of genetic algorithm because of higher speed and stability of decision searching. The results of the frame members optimization are provided.

Keywords: genetic algorithm, steel multistory frame member, GA model.

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ОПТИМИЗАЦИЯ ЭЛЕМЕНТОВ СТАЛЬНОЙ МНОГОЭТАЖНОЙ РАМЫ С ИСПОЛЬЗОВАНИЕМ ГЕНЕТИЧЕСКОГО АЛГОРИТМА

Аннотация. Настоящее исследование направлено на разработку и применение модели генетического алгоритма для оптимизации стальной многоэтажной рамы. Разработанная модель показывает лучший результат по сравнению с классической моделью как по скорости, так и по устойчивости поиска решения. Приведен пример с результатами оптимизации элементов рамы.

Ключевые слова: генетический алгоритм, стальная многоэтажная рама, модель генетического алгоритма.

Genetic algorithms (GAs) are stochastic search methods in multidimensional space with their parameters interacting in a complicated manner. The GA efficiency can be increased significantly provided a GA model was successfully selected. The optimization of a model facilitates both stability and speed of decision making process which is highly essential in GA application.

Algorithm speed is estimated by the time needed for the required quality of population to be reached or its convergence. Search stability is estimated by the ability of algorithm to improve the quality of population from generation to generation and the resistance of algorithm to local extremum. The GA model suggested by John H. Holland in his work "Adaptation in Natural and

Column section under optimization *Rafter section under optimization*

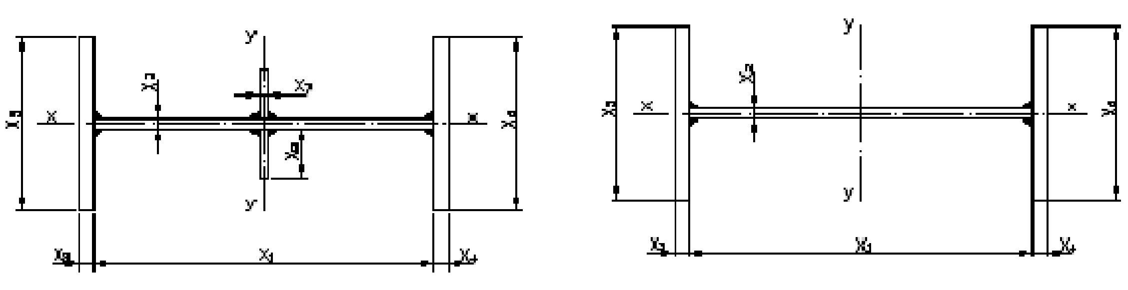

Fig. 1. Steel frame under optimization

Artificial Systems" (1975) is considered to be the classical one. The model includes the fixed number of population and gene bit width, proportional and random samplings of individuals for cross-breeding. Crossover and mutation are binary; next generation is formed by offspring replacing their parents [1]. Though the classical GA model explains GA operation explicitly, it fails to be the most effective model.

This paper considers the GA model for optimization of members ofmultistory steel frame. The optimization aims to define design variables $\{x_1 \dots x_n\}$ of a member in terms of minimum structure weight satisfying strength, stiffness, buckling and overall stability constraints.

The classical GA was created on the first stage of model development. The research of gene operator interaction, the parameter impacts (population size, operators in use, operator probabilities, etc.) on the algorithm operation as well as chromosome representation method was carried out. The resulting GA model used for steel frame optimization is as follows: initial population is generated randomly; the population size and gene bit width are fixed. The selection is supposed to be elitist, although in some works, e.g. [2, 3] it is considered as rather "weak" in terms of search efficiency due to the potential threat of premature convergence that is balanced by standard outbreeding of parent selection. Such combination proved to be the most effective one. Breeding pair technique referred to as standard outbreeding was based on the distant "relationship", i.e. the distance between members of population from the standpoint of Hamming distance between chromosome sets of individuals. Thus, outbreeding generates couples from the most distant individuals and aims to prevent algorithm convergence with earlier solutions found forcing algorithm to search new and uninvestigated fields.

Crossover operator should be considered as either single-point or double-point, and mutation operator with low mutation probability should be considered around 3%. Meanwhile, the use of fixed number of breeding pairs proves to be highly efficient, i.e. the classical scheme with the number of offspring being restricted by the application of so called crossover probability is abandoned. Either Grey codes or floating point coding are preferred to be used when choosing a coding type. Binary encoding complicates the search adding extra breaks.

Genetic algorithms provide enormous data for research thanks to huge number of modifications and parameters. Slight modification of any parameter frequently results in unexpected outcome improvement. The development of proper optimization model for multistory steel frame using GA enables to find optimum or near-optimum solutions fast and efficiently. We illustrate the possibilities of the algorithm by the example of frame member optimization taking into account design data presented in [4] (Table 1). The results of the program based on GA can be obtained by

Table 1

Design data

# member	Rated forces				Effective length	
	N, kN	Q, kN	M, kNm	R, MPa	l_x, m	l_y, m
1	-20481.8	-163.7	-1569.6	380.0	22.29	7.1
2	-17346.0	-219.1	-1022.3	290.0	17.89	6.6
3	-8776.5	-790.8	-2092.7	290.0	11.62	3.6
Rafters						
1	200	1000	3000	210	1.2	
2	250	2100	4500	290	0.6	
3	150	3300	8000	380	0.4	

Table 2

Values obtained by the program using GA

Design parameter values in columns (with regard to specification of structural steel cross-sections)							
# member	X_1, cm	X_2, cm	$X_3 = X_4$, cm	$X_5 = X_6$, cm	X_7, cm	$2X_8$, cm	Sectional area A, cm^2
1	184.4	1.8	1.8	85.0	1.4	42.0	699.71
2	168.0	1.4	2.5	80.0	1.2	50.0	695.20
3	167.2	1.4	2.0	48.0	1.2	30.0	462.08
Design parameter values in rafters (continuous solution)							
1	152.41540	1.13867	1.47002	44.10206	-	-	303.2132
2	142.8698	1.38489	1.71598	44.44637	-	-	350.3987
3	185.77020	1.85466	1.94939	30.00061	-	-	461.5067

considering either specification of structural steel cross-sections or continuous problem statement (Table 2). The speed of the suggested algorithm is 10 % higher and the search stability is 10 % higher than those of the classical model.

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