

Weight Minimization of Trusses with Natural Frequency Constraints

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Abstract

The article presents the optimization of trusses subject to natural frequency constraints. Three planar trusses (10-bar, 37-bar and 200-bar structures) and three spatial trusses (52-bar, 72-bar and 120-bar structures) are surveyed. These structures are very common and there are similar studies in literature. However, the differences in this study are the quality of results and new groups of elements in 200-bar and 52-bar structures.

Although Differential Evolution (DE) has been proposed since 1997 and attracted many studies, there is not much application of DE to truss optimization with natural frequency constraints. In this paper, DE is employed to find the optimal cross-section sizes and node coordinates. Constraint-handling technique is only based on a clear distinction between feasible solutions and infeasible solutions. Parameters of DE are as follows: population $N = 50$ (except $N = 150$ for 200-bar truss), crossover constant $CR = 0.9$, mutation constant $FM = 0.5$, number of iterations $I = 150$. Each problem is performed in 50 independent runs (except 100 runs for 200-bar truss).

The obtained results are equivalent to or better than solutions in literature. The convergence is rapid in around first 50 iterations. Especially, for 200-bar truss the use of 19 element groups instead of 29 groups, which is common in literature, reduces space search and makes the minimum weight improved. Brief data of problems are given in the following table.

Table: Parameters and the minimal weight of trusses

Parameters	Unit	Data of problems					
		10-bar	37-bar	200-bar	52-bar	72-bar	120-bar
Modulus of elasticity, E	N/m ²	6.98 × 10 ¹⁰	2.1 × 10 ¹¹	2.1 × 10 ¹¹	2.1 × 10 ¹¹	6.98 × 10 ¹⁰	2.1 × 10 ¹¹
Material density, ρ	kg/m ³	2770	7800	7860	7800	2770	7971.81
Frequencies constraints	Hz	$\omega_1 \geq 7$ $\omega_2 \geq 15$ $\omega_3 \geq 20$	$\omega_1 \geq 20$ $\omega_2 \geq 40$ $\omega_3 \geq 60$	$\omega_1 \geq 5$ $\omega_2 \geq 10$ $\omega_3 \geq 15$	$\omega_1 \leq 15.916$ $\omega_2 \geq 28.648$	$\omega_1 = 4$ $\omega_3 \geq 6$	$\omega_1 \geq 9$ $\omega_2 \geq 11$
Cross-section bounds	m ²	[0.645 × 10 ⁻⁴ , 40 × 10 ⁻⁴]	[10 ⁻⁴ , 10 ⁻³]	[0.1 × 10 ⁻⁴ , 30 × 10 ⁻⁴]	[10 ⁻⁴ , 10 ⁻³]	[0.645 × 10 ⁻⁴ , 30 × 10 ⁻⁴]	[10 ⁻⁴ , 129.3 × 10 ⁻⁴]
Nodes coordinate bounds	m	No	Yes	No	Yes	No	No
Minimal weight W_{\min}	kg	524.56	359.45	2296.38	191.28	324.36	8710.90