Journal of Information Systems Engineering and Management
2025, 10(25s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

Cost Optimization of Tubular Columns through Non-Traditional Methods

Jagan T[1], Elizabeth Amudhini Stephen[2]
[1]Department of Mathematics, Rathinam College of Arts and Science, Eachanari, Coimbatore, Tamil Nadu, 641021
[2]Department of Mathematics, Karunya Institute of Technology and Sciences, Coimbatore, Tamil Nadu, 641114

ARTICLE INFO
Received: 21 Dec 2024
Revised: 12 Feb 2025
Accepted: 25 Feb 2025

ABSTRACT
Introduction: : One of the most significant recent advancements in high-rise structural form is the tubular column. For reaching enormous heights, it features a typically efficient and simple-to-assemble design. As non-traditional approaches for minimizing the cost of tubular columns, this study describes the ABC algorithm, Fireworks, Ant lion, Auction, Greedy, Spiral, Elephant herding, Lawler's, bacterial colony, and pattern search. We looked at ten artificial optimization methodologies in order to discover the optimum strategy for reducing the total cost of a tubular column problem. We arrive at a decision regarding which technique is optimal for solving the tubular column problem..
Keywords: Tubular columns, Optimization techniques, ABC algorithm, Fireworks, Ant lion, Auction, Greedy, Spiral, Elephant herding, Lawler's, bacterial colony, and pattern search.

INTRODUCTION

In high-speed winds, tall buildings with more tubular designs are more prone to oscillation. Even if the oscillations do not pose a threat to the structure, they may cause occupant discomfort, necessitating a thorough study of building motion for serviceability. For early design, approximate analysis is the most economical solution. To verify the results, advanced computational approaches such as finite element analysis should be used because they can throw light on the use of various structural elements and their sizes. Approximate methods also simplify numerical calculations, saving time and improving computational efficiency.

The social spider optimization (SSO) algorithm, a new meta-heuristic optimisation method that has demonstrated promising results in optimising frame architectures, was utilised to obtain the best designs. The social spider optimisation (SSO) algorithm, a new meta-heuristic optimisation method that has demonstrated promising results in optimising frame architectures, was utilised to obtain the best designs (Ahmed Paksoy 2024). There are several estimated ways for assessing the reaction of framed tube tall buildings to lateral stresses (Celal Cakiroglu 2021). The seismic demand of a structure is totally determined by its natural periods, therefore identifying vibration periods for tall buildings is crucial. Exact free vibration analysis of tall buildings using finite element methods and sophisticated computer programmers takes a considerable time and effort since tubular constructions contain many structural elements and joints. As a result, finite element models can only be utilised for this purpose in the early stages of study and design. As a result, it's better to look for an approximation method that saves time and effort while also producing the desired outcome with a limited margin of error (Safa D 2024). The frequencies of nature We'll go over the purpose of the problem in the next session, which is to minimize given a set of restrictions. We created an algorithm and put it to the test, with the results being presented and compared to other non-traditional optimization methods.

PROBLEM FORMULATION

The ideal design of the tallest tubular column under self-weight is sought given a specific volume of material and the elastic characteristics of that material. Because the height at which an unloaded tubular column will buckle is

connected to the first Eigen value of a Sturm–Lowville operator, this problem can be phrased as an extremal Eigen value problem. The spectrum associated with physical designs is defined using annular cross-section columns. Rearrangements are used to verify the existence of an optimal design over a specific class of designs. Also established are the necessary requirements for optimality in that class. (2020, Duong Thanh Huan)

Figure 1 illustrates the tubular column. The upper and lower boundaries of the tubular column are supported by

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hinged bearings and are axially loaded with a load (P). In terms of compressive and buckling forces, the types of restraints utilised on the column are critical. The column's compressive stress must be less than the tubular column's yield stress.

Table 1.Design constants of the tubular column

Symbol	Definition	Value
P	Axial force	2500 kgf
σ_y	Yield stress	500 kgf/cm^2
E	Modulus Of Elasticity	0.85x10^{6}kgf/cm^2
P	Density	0.0025kgf/cm^3
L	Length Of Column	250cm

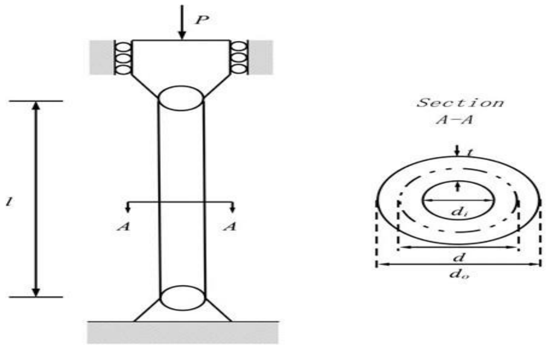


Fig 1. Tubular column

MATHEMATICAL FORMULATION

Use a compressive load of P = 2500 kg f to save money. The yield stress of the material utilised in the column is 500 kg f/cm2, the elasticity modulus (E) is 0.85 X 106 kg f/cm2, and the weight density is 0.0025 kg f/cm3. The length of the column is 250 cm. The column stress should be less than the buckling and yield stresses. There are no columns on the market that are between 0.2 and 0.8 cm thick and have a mean diameter of 2 to 14 cm.

The cost of the column is calculated as 5W + 2d, where W is the weight in kilogrammes force and d is the column's mean diameter in centimetres.

The cost of the column is calculated as 5W + 2d, where W is the weight in kilogrammes force and d is the column's mean diameter in centimetres..

The mean diameter (d) and tube thickness (t) are the design variables:

$$X = \begin{Bmatrix} x_1 \\ x_2 \end{Bmatrix} = \begin{Bmatrix} d \\ t \end{Bmatrix}$$

The objective function that must be reduced to its simplest form

$$f(X) = 5W + 2d \quad (1)$$

$$= 5\rho l\pi\, dt + 2d$$

$$= 9.82dt + 2d$$

$g_1(X)$: The behavior constraints can be expressed as

Stress induced ≤ yield stress

Stress induced - yield stress≤ 0

$$induced\ stress = \sigma_i = \frac{P}{\pi\, dt} = \frac{2500}{\pi\, dt}$$

Yield stress =500

$$g_1(X) = \frac{2500}{\pi dt} - 500 \leq 0$$

$$g_1(X) = \frac{35}{22dt} - 1 \leq 0 \quad (2)$$

For a pin-connected column, the buckling stress is given by

Buckling stress $= \sigma_b = \frac{Euler\ bucklingload}{cross{-}sectional\ area} = \frac{\pi^2 EI}{l^2}\frac{1}{\pi\, dt}$

Where

I= second instant of area of the column's cross section

$$= \frac{\pi}{64}(d_0^4 - d_i^4)$$

$$= \frac{\pi}{64}(d_0^2 + d_i^2)(d_0 + d_i)(d_0 - d_i)$$

$$= \frac{\pi}{64}[(d+t)^2 + (d-t)^2]\ X\ [(d+t) + (d-t)][(d+t) - (d-t)]$$

$$= \frac{\pi}{8} dt\ (d^2 + t^2) = \frac{\pi}{8}\ dt\ (d^2 + t^2)$$

$g_2(X)$The cross section constraints can be expressed as

Stress induced ≤ buckling stress

Stress induced - buckling stress ≤ 0

$$g_2(X) = \frac{2500}{\pi x_1 x_2} - \frac{\pi^2(\ 0.85\ X10^6)(d^2+t^2)}{8(250)^2} \leq 0$$

$$g_2(X) = \frac{8X2500X(250)^2}{\pi^3(dt)(0.85X106)(d^2+t^2)} - 1 \leq 0 \quad (3)$$

The side constraints are given by

$$2 \leq d \leq 14$$

$$0.2 \ \leq t \leq 0.8$$

Which can be expressed in standard form as

$$g_3(X) = \ -d + 2.0 \ \leq 0 \quad (4)$$

$$g_4(X) = \ d - 14.0 \ \leq 0 \quad (5)$$

$$g_5(X) = \ -t + 0.2 \leq 0 \quad (6)$$

$$g_6(X) = \ t - 0.8 \ \leq 0 \quad (7)$$

Minimize: f (d, t) = 9.28dt + 2d

Subject to

$$g_1 = \frac{35}{22dt} - 1 \leq 0$$

$$g_2 = \frac{8X2500X(250)\ \hat{}2}{\pi 3(dt)(0.85X106)(d\hat{}2+t\hat{}2)} - 1 \leq 0$$

$$g_3 = \frac{2.0}{d} - 1 \leq 0$$

$$g_4 = \frac{d}{14} - 1 \leq 0$$

$$g_5 = \frac{0.2}{t} - 1 \leq 0$$

$$g_3 = \frac{t}{0.8} - 1 \leq 0$$

Where

d – Diameter of the column t – Thickness of the column L – Length of the column

E – Elasticity of the column ρ - Density of the column

OPTIMIZATION

The problem is solved using ten non-traditional optimization strategies. These ten strategies are used to determine the global optimum for the non-linear optimization problem for quick processing.

COMPARATIVE RESULTS

Table 2 shows the results of comparing turning machining parameters using ten non-traditional optimization algorithms. Since non-traditional optimization methods provide the global optimum solution, each problem is executed for 20 tries.

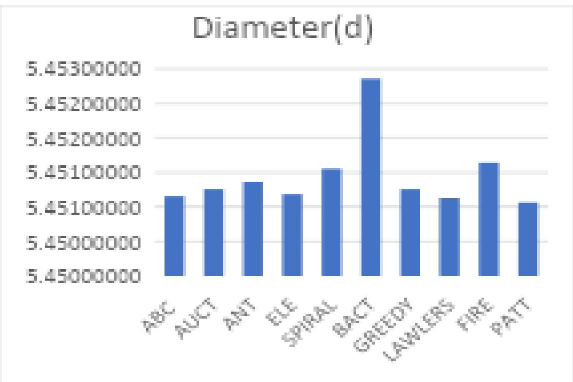
Table 2 Comparative Results of Non-traditional Optimization Methods

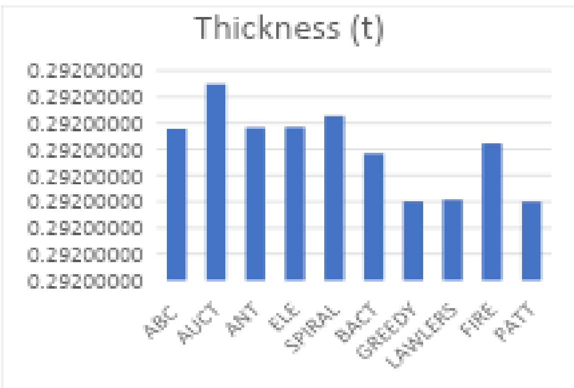
Trial No.	ABC	AUCT	ANT	ELE	SPIRAL	BACT	GREEDY	LAWLERS	FIRE	PATT
d(cm)	5.45065	5.45074	5.45232	5.45065	5.45104	5.45236	5.45075	5.45062	5.45113	**5.45057**
t(cm)	0.291956	0.291982	0.291947	0.291948	0.291972	0.291936	**0.291900**	0.291901	0.291945	**0.291900**
fmin	25.66906	25.67076	25.67640	25.66863	25.67170	25.67603	25.66666	25.66614	25.67071	**25.66579**

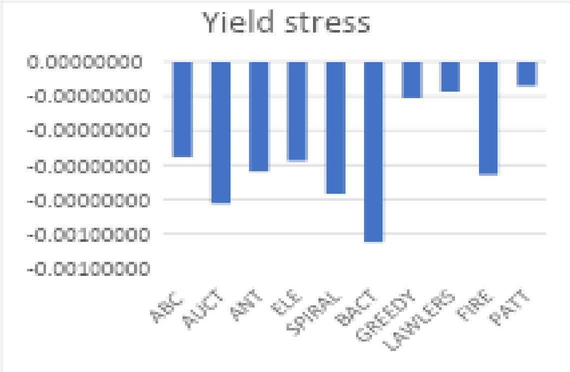
The statistical results in Table 3 show that pattern search and the Firework algorithm are the most successful methods for addressing this problem with the lowest best values. When compared to the referred algorithms, it is obvious that the Pattern search algorithm can converge quickly to the near best answer from the early iterations.

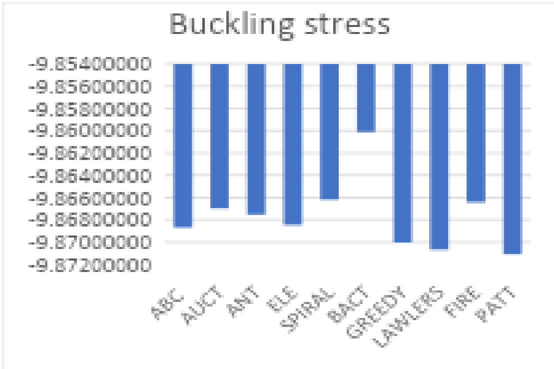
Table.3 Statistical results of the used algorithms for the tubular column problem

Algorithm	Best	Mean	Worst	SD	FEs
ABC	25.66896	25.66896	25.66908	0.00015617	15000
AUCT	25.67604	25.67604	25.67588	0.00055186	15000
ANT	25.66946	25.67076	25.67124	0.0312183	15000
ELE	25.66917	25.67007	25.80903	0.00048766	15000
SPIRAL	25.67082	25.6726	25.67229	0.0011001	15000
BACT	25.67604	25.67604	25.67588	0.00003757	15000
GREEDY	25.66656	25.66657	25.66672	0.0001408	15000
LAWLERS	25.66613	25.66619	25.66619	0.0004173	15000
FIRE	25.67045	25.67089	25.67074	0.0000955	15000
PATT	**25.66579**	**25.66579**	**25.66579**	**0.00000000**	15000









RESULTS AND DISCUSSION.

Ten non-traditional optimization approaches are used to tackle the cost minimization of tubular column problems. MATLAB is used to implement the ten algorithms. The issue is made up of 20 trails. When compared to other approaches, the diameter of the pattern search algorithm (5.45057cm) is the smallest, followed by Lawler's algorithm (5.45062cm). When compared to other approaches, the pattern search algorithm (0.291900cm) and greedy algorithm (0.291900cm) have the smallest thickness (t). When compared to other approaches, the pattern search algorithm (25.66579) has the lowest overall cost, followed by Lawler's algorithm (25.66614). As a result of the aforementioned, we can conclude that pattern search algorithms have a low evaluation.

CONCLUSION

Ten algorithms are used to solve the tubular column problem in this research. The results for these ten non-traditional methods evaluated effectively are reported in ABC algorithm, Auction, Spiral, Ant lion, Elephant herding, bacterial colony, Greedy, Lawler's, Fireworks, and pattern search. When compared to other approaches, the pattern search algorithm (25.66579) has the lowest overall cost, followed by Lawler's algorithm (25.66614). All of the aforementioned results suggest that pattern search is superior to other methods. Finally, we arrive at the conclusion that the pattern search approach has the lowest cost.

ACKNOWLEDGEMENTS

The author JT thanks the Department of Mathematics, Rathinam College of Arts and Science, Eachanari, Coimbatore for the partial support through the DBT STAR COLLEGE SCHEME (SAN No.102/IFD/SAN/484/2024-25), Government of India.

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