Optimization of a Cantilever Beam for Minimum Cross Section Area under Bending Stress Using Genetic Algorithm

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Abstract: This research is related to comparison of minimum area evaluated by genetic algorithm under the bending condition on cantilever beam. There are many use of cantilever beam use in construction and in machine element. This optimization will help to save material which will be beneficial for industries. Generally rectangular cross section beam is used but if it is optimized by genetic algorithm for minimum area then requirement of material reduce. In this research triangle, rectangle and circle cross section beam is optimized under strength and deflection constraints.

***Index Terms* – Genetic Algorithm, Cantilever Beam, Cross Section, Bending Strength**

I. INTRODUCTION

Beams are widely in different applications such that in building, in transportation, in machine elements etc. Design of cantilever beam spring has some constraints such that area, strength and deflection. Design is complicated with the traditional methods so genetic algorithm has used for optimum results. Vijayarangan et al. [1] used GA technique for the design optimization of leaf spring. He obtained the optimum value of the design parameters for minimum weight of the spring. Different methods of optimization algorithm, i.e. traditional and non-traditional, were proposed by Kalyanmoy Deb [2] presented the non-traditional algorithms with the help of numerical examples. Surendra et al [3] optimized Helical gear for beam strength of helical gear and gave influencing factors in beam strength like contact ratio, gear ratio, helix angle, face width, module, pressure angle and their combined effects that enhance the effectiveness and performance of the helical gear. Yallamti et al [4] involved about the optimization of spur gear set for its center distance, weight and tooth deflections are taken as an objective functions and the decision variable such as module, face width and number of teeth on pinion, and subjected to constraints namely, bending stress, contact stress and optimized spur gear problem. Diptesh et al [5] studied various crossover and mutation operators for genetic algorithms to solve the indexing problem and concluded that the combination of the alternating edge crossover operator and the invert mutation operator output the best results for this problem. Masoud et al [6] introduced an optimization procedure for producing biodiesel and increased the production of the fuel during chemical reactions, an interaction between several substances. Temperature monitored and optimized using multi objective genetic algorithm. Rames et al [7] presented an Elitist Non-Dominated Sorting Genetic Algorithm for solving the Reactive Power Dispatch problem. The optimal RPD problem was a nonlinear constrained multi-objective optimization problem where the real power loss and the bus voltage deviations were minimized. Many research have done by genetic algorithm in engineering design so this approach of design can be used to find minimum area of cross section under bending load.

II. Problem Formulation and Results

A design problem of cantilever beam is taken under condition which is shown in table 1 and parameters on which genetic algorithm works shown in table 2.

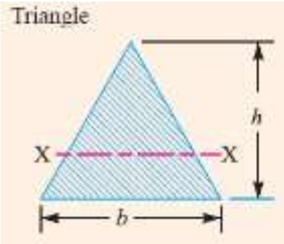
Table 1 Parameters for design of cantilever beam.

Maximum deflection	Length of beam (L)	Applied Load (P)	$Allowable\ bending\ strenth\ (\sigma_{allowable})$	Modulus of elasticity (E) of material
0.1L	1000mm	1000N	220Mpa	200Gpa

Table 2 Parameters for genetic algorithm

Number of populations	No. of bits in one chromosome	Type of coding	Type of crossover	Crossover probability	Probability of mutation	Type of selection	Number of Iterations
180	10	Binary	Single point crossover	0.8	0.06	Rolette Wheel	200

- Firstly triangle cross section beam is taken with all constrains which is used in design. Equation (1) shows the area of triangle or objective function for minimization which is shown in fig (1), equation (3), and equation (4) show bending strength and deflection of centiliter triangle beam which are constraints.



$$Area = A = b \times h \qquad (1)$$

$$Section\ Modulus = Z_{xx} = \frac{bh^2}{12} \qquad (2)$$

$$Bending\ stress = \sigma_b = \frac{M}{Z_{xx}} < \sigma_{allowable} \qquad (3)$$

Fig 1

$$Diflection = \delta = \frac{WL^3}{3EI} < \delta_{max} \qquad (4)$$

Table 3 shows optimized results by genetic algorithm where area of cross section 1387mm squire is calculated.

Table 3 Result evaluated by GA for triangle cross section

b(mm)	h(mm)	A(mm sqr)
14.0762	197.0674	1.3870e+003

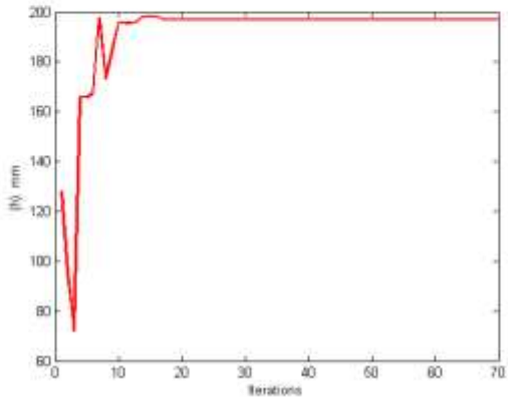


Fig 2 variation in height with iterations

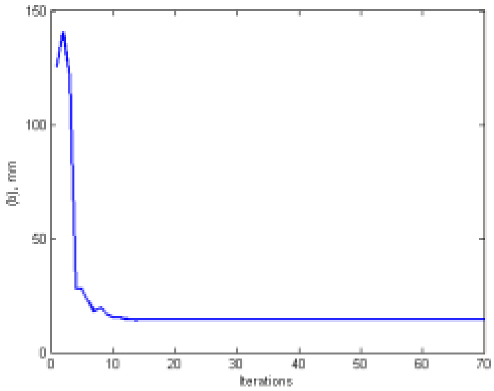


Fig 3 variation in base with iterations

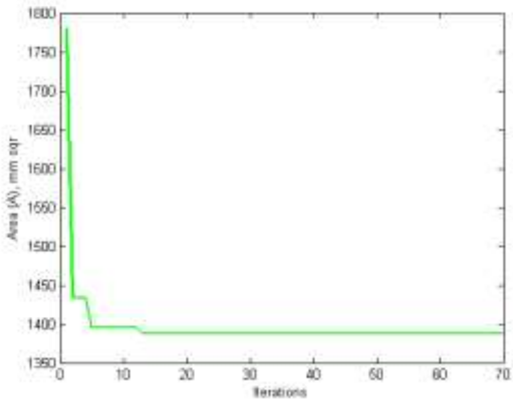
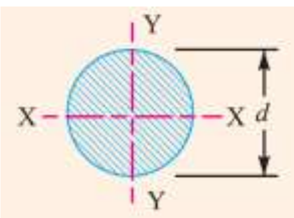


Fig 4 variation in area with iterations

Fig 2 to fig 4 are showing the variation in parameters of triangle with respect to iterations of genetic algorithm. Fig 4 is for area and it is minimized in 15 iterations.

- A beam of circle cross section of diameter (d) and a bending force is about axis x-x at the end of beam. Equation (5) and equation (6) show the area and section modulus for circular cross section.



$$Area = A = \frac{\pi}{4} d^2 \qquad (5)$$

$$Section\ Modulus = Z_{xx} = \frac{\pi}{32} d^3 \qquad (6)$$

Fig 5

Table 3 shows optimized results by genetic algorithm where area of cross section 4307 mm squire is calculated.

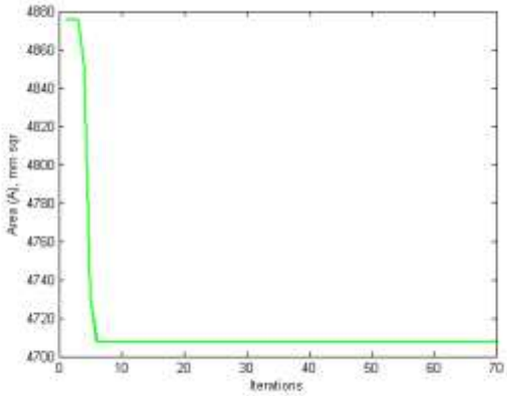


Fig 6 variation area with iterations

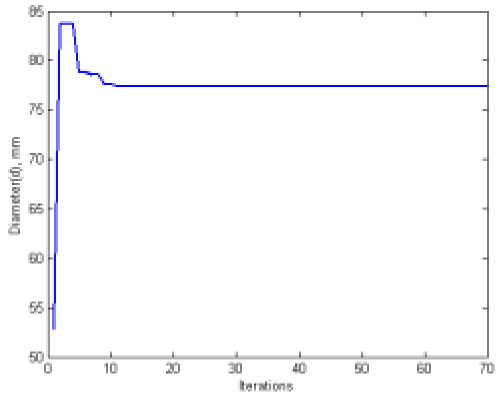
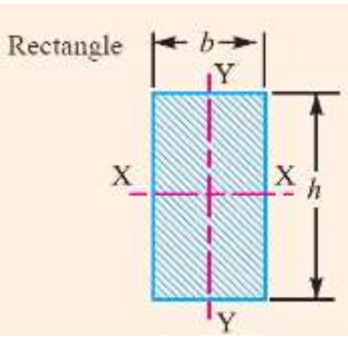


Fig 7 variation in diameter with iterations

Table 4 Result evaluated by GA for circle cross section

r(mm)	A(mm sqr)
77.4194	4.7075e+003

- A rectangular section cantilever beam under bending stress is taken. Equation (7) and Equation (8) are showing area and section modulus.



$$Area = A = b \times d \tag{7}$$

$$Section\ Modulus = Z_{xx} = \frac{bh^2}{6} \tag{8}$$

Fig 8

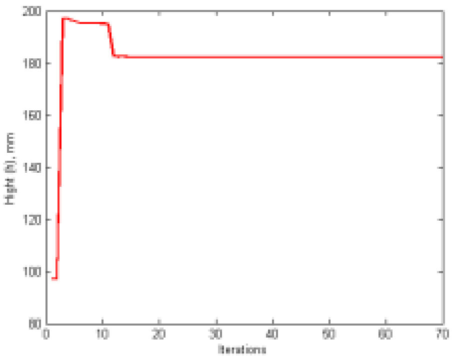


Fig 9 variation in height with iterations

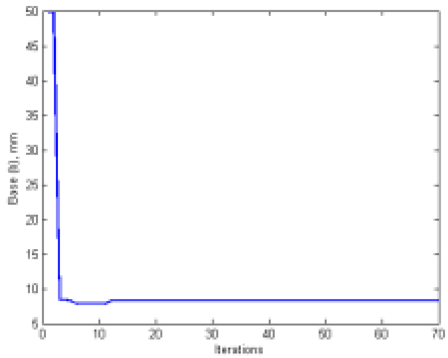


Fig 10 variation in base with iterations

Fig (9) and fig (10) variation in base and height with respect to iterations and fig (11) is showing change in area with iterations and it is achieved after 15 iterations which is 1497 mm squire.

Table 5 Result evaluated by GA for rectangular cross section

b(mm)	h(mm)	A(mm sqr)
8.2111	182.4047	1.4978e+003

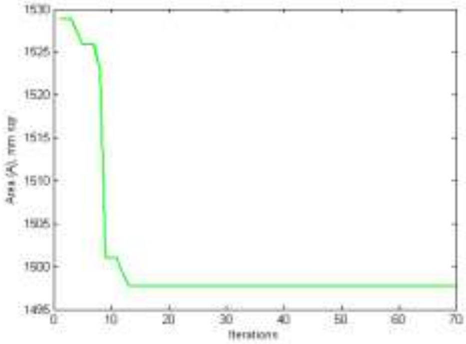


Fig 9 variation in area with iterations

Table 6 Comparison of cross section area evaluated by genetic algorithm

Triangle	Rectangle	Circle
1.3870e+003	1.4978e+003	4.7075e+003

III. Discussion and Conclusion

Minimum area under bending load condition is achieved after applying genetic algorithm for different section and it is found that triangle cross section requires less area than rectangular and then circle. A little consideration of table 3 shows that height of triangle require more than base so we can conclude that triangle cross section should be prior and height of triangle should be high as much as possible. This approach of optimization is proved beneficial and we can use this in engineering, management and others area where many variables are present.

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