ABSTRACT

Optimisation of steel lattice towers is a large design space problem with discrete variables such as area of cross section of members, base width and bracing patterns. Variables such as shape of section, bracing pattern and secondary bracings are difficult to be quantified in optimisation by conventional methods. In many situations, classical optimisation methods face certain difficulties in solving practical problems. Most of the conventional optimisation techniques are based on mathematical programming. Formulation of practical design problems into a mathematical format acceptable to the algorithm is very complicated. Function involved has to be continuous and continuously differentiable. But, many functions are noisy and discontinuous. Because of these limitations in conventional optimisation techniques, structural engineers face difficulties in implementing optimisation procedures for design problems. The limitations of conventional optimisation techniques can be overcome to a large extent by non-traditional method like genetic algorithms.

Genetic algorithms are non-traditional search algorithms that are based on the concepts of natural selection and natural genetics. Genetic algorithms use objective function information, not derivatives or auxiliary knowledge. Direct use of coding, search from a population and randomised
operators make a genetic algorithm robust. Genetic algorithms can be applied to large-design-space problems and are suitable for discrete optimisation of engineering structures such as lattice towers. This study explains the difficulties that arise in optimisation using conventional methods and brings out the advantage of using genetic algorithm for optimisation problems. A new approach for optimising lattice towers is developed, tested and justified.

Series of benchmark problems are studied using genetic algorithms. Typical 10-bar truss, 25-bar transmission tower and 72-bar tower structure are considered. To improve the performance of the algorithm, logically evolved penalty functions are developed and introduced in the algorithm. These vary according to constraints, type of problem and trend of results. For the referred benchmark problems, the results obtained using the above approach are compared with the results reported in literature. The results obtained in this study are found to be more optimal than the results given in the literature. Genetic Optimisation Algorithm for Towers (GOAT), an algorithm and the associated software developed for structural optimisation for lattice structure is used throughout this study.

Practical tower design involves a number of discrete variables, and many codal provisions. Stress and stability constraints, which are considered generally for the tower design, increase the total number of constraints along
with number of variables. To illustrate the use of genetic algorithm for optimisation of steel lattice towers, a typical 132 kV single circuit transmission line tower is optimised and the results are presented. Discrete values from Indian Standard equal angle steel sections are employed for cross sectional areas of members as design variables and codal provisions are considered as constraints on optimisation.

The efficiency and speed of optimisation depend to a large extent on the number of design variables. Algorithms, which work very efficiently when the number of variables is small, do not work that well when this number becomes large. When the search space becomes larger and larger, convergence to optimal solution takes more and more number of generations. Many times the solutions obtained are less optimal or infeasible as the probability of constraint violation increases when total number of constraints increases. These complexities with constraints make convergence difficult. New approaches and simple strategies, which can account for the complexities and practical considerations, are required when the search space is large.

Considering all these difficulties a new approach is developed for optimisation of steel lattice towers by combining genetic algorithms with object-oriented approach. The purpose of this approach is to eliminate the difficulties that arise in handling large size problems. Improved search and
rapid convergence are obtained by considering the tower as a set of small objects and combining these objects into a system. This is possible with serial cantilever structures such as lattice towers. The tower is conceived as a series of panels, which can be classified as separate objects as they possess independent as well as inherent properties. This considerably reduces the design space of the problem and enhances the result. A convincingly optimal solution is obtained when the problem is small. An optimisation procedure for steel lattice tower using objects and genetic algorithms is presented. The algorithm with practical design considerations used in this approach is described. To demonstrate the approach, a typical tower with practically occurring constraints has been considered for discrete optimisation analysis using the new approach and the results are compared with the results obtained through a normal approach in which the full tower is considered. It is found that an efficient solution is obtained as the problem size is reduced, with no change in structural behaviour. Object-oriented approach has yielded a solution, which is 17.7% less in weight than when the tower as a whole is optimised. Computational time is reduced and convergence is much faster.