CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter the literature available within the purview of the objectives of the present study is reviewed under two different heads: Non-Structural Applications of Ant Colony Optimization algorithm and Algorithms for Discrete Structural Applications. The need for the proposed work is also discussed.

2.2 NON-STRUCTURAL APPLICATIONS OF ANT COLONY OPTIMIZATION ALGORITHM

Coloni et al (1992) have introduced Ant Colony algorithm and discussed some of the essential properties of ant colony optimization algorithm by considering the Traveling Salesman Problem (TSP) as a vehicle. They have also made a parametric study on various control parameters of Ant Colony Optimization and compared the results obtained using their algorithm with those obtained using other specialized algorithms available for TSP. Based on the results, they have concluded that Ant Colony Optimization algorithm is an effective tool to avoid algorithm termination at sub-optimal points.

Dorigo et al (1996) have made an attempt on the application of ant based algorithm to solve asymmetric Traveling Salesman Problem, Quadratic
Assignment Problem and Job-Shop Scheduling problem. They have discussed some of the essential features of Ant Colony Optimization such as positive feedback mechanism, distributed computing and the use of constructive greedy heuristics. They have substantiated the viability of their model with the help of their results obtained using the algorithm.

Dorigo and Gambardella (1997a) have made an attempt on the application Ant Colony System (ACS), a distributed algorithm for solving Traveling Salesman Problem. They have adopted a different kind of trail update rule namely “pseudo-random proportional rule” and made a study on pheromone behavior and its performance. Based on their results they have concluded that ACS is an effective tool for solving problems like TSP when compared to other approaches like simulated annealing.

Botee and Bonabeau (1998) have discussed the fundamental concepts involved in Ant Colony System (ACS) and Ant Colony Optimization (ACO) algorithms. They have discussed the application of ACS and ACO algorithm for Traveling Salesman Problem (TSP) and suggested a new approach of simple ACO for TSP. In their approach, they have evolved some important parameters like number of ants, importance of trail intensity and desirability etc... using Genetic Algorithm instead of manual tuning and the same has been adopted for finding the shortest path. They have concluded that the automated parameters using GA produce better quality solutions than the manually tuned parameters.

Dorigo et al (1999) have dealt with an overview of recent works done using ACO. In the first part of their article, they have reviewed some of the biological findings of the real ants and compared the similarities and differences of virtual ants with real ants. In the second part they have discussed the application of various forms of ACO algorithm to different
types of combinatorial optimization problems such as Traveling Salesman Problem, Quadratic Assignment Problem, Job-Scheduling Problem and so on. In their conclusion they have projected many potential advantages of ACO over other algorithms.

Dorigo and Stuzzle (2001) have discussed some of the essential properties of Ant Colony Optimization algorithm based on their carefully conducted experiments and proposed a simplified ant based algorithm called S-ACO. They have applied S-ACO algorithm for finding the shortest paths in graphs. Based on their experimental findings they have drawn few significant conclusions. In their conclusions they have emphasized the importance of parameters like pheromone evaporation, importance of trail intensity etc... for getting fast convergence of the solution.

2.3 ALGORITHMS FOR DISCRETE STRUCTURAL APPLICATIONS

Rajeev and Krishnamoorthy (1992) have used Genetic Algorithm, for minimizing the weight of a space truss by treating it as a constrained optimization problem. They have considered the design variables as discrete. Since GAs are best suited for unconstrained optimization problem, they have applied a penalty-based transformation to transform the constrained problem to unconstrained optimization problem. From the observation of their numerical experiments, they have concluded that GAs are best suited for discrete structural optimization. Also they have pointed out certain limitations that GAs require more number of functional evaluations to find an optimal solution. They have brought out that there is further scope to improve GAs by using more number of genetic operators to increase the efficiency of the algorithm.
Dhingra and Bennage (1995a) have made an attempt on the use of a memory-based combinatorial optimization technique called Tabu Search (TS), for the optimal design of Discrete-Continuous variable structural optimization problems. They have discussed some of the salient features of Tabu Moves, Tabu Restrictions and Aspiration Criteria. They have adopted a non-Markovian function to constrain the search. From the numerical investigations, they have drawn many significant conclusions on Tabu Search for structural optimization.

Bennage and Dhingra (1995a) have adopted Monte-Carlo method and Simulated Annealing (SA) for multi-variable structural optimization. They have formulated the objective function using a cooperative game theoretic approach to generate the optimal structural designs. They (1995a) have compared the optimal design obtained using SA with those obtained using some gradient-based and discrete optimization techniques. Based on the results, they have concluded that SA has much potential advantages to solve discrete structural optimization problems over other algorithms.

Dhingra and Bennage (1995b) have made an effort on the application of SA for topological optimization of truss structures. They have facilitated the proposed algorithm to generate and evaluate some alternate structural topologies of truss structures. In addition, the proposed method is facilitated with a procedure to introduce some new structural members in an existing topology. They have proved the superiority of their model through series of truss problems.

Bennage and Dhingra (1995b) have made an attempt on the application of Tabu Search for topology optimization of space truss structures. The optimization problem was formulated as a constrained optimization problem with mixed discrete and continuous design variables.
Displacement, stress and local/global buckling constraints were considered in the problem formulation. The algorithm was formulated in such a way that it could be capable of taking multiple load conditions. They have compared the optimal designs obtained using Tabu Search with those obtained using ground-structure approach. From the numerical experiments they have concluded that their model involves much computational burden to generate better quality solution owing to the necessity to optimize each trial topology.

Ulker (2001) has applied the interactive computing capability of Microsoft Spread sheets as an effective optimization tool for minimizing the weight of space truss. He has considered the optimization problem as constrained optimization problem by incorporating displacement, stress and buckling constraints. The applicability of the spreadsheets has been effectively demonstrated through series of space truss problems. He has compared the minimum weight of a 25-bar space truss (i.e. a standard benchmark problem in the field of structural optimization) with the work of Saka (1990).

Soremekun et al (2002) have discussed some of the fundamental concepts of GA and its applicability for optimum stacking sequence of composite laminates. They have applied an optimization technique called, DARWIN (i.e. commercial software; an advanced genetic algorithm computer coding developed by ADOPTECH) for finding the optimum stacking sequence of two-dimensional laminated composite panels. They have noted the significance of DARWIN for getting an optimal stacking sequence of two-dimensional laminated composite panels.

Hansel et al (2002) have proposed two alternative approaches namely, a heuristic algorithm and genetic algorithm for minimizing the total weight of laminated composite structures. They have divided the optimization
into two different phases. In the first phase, a stressed-base heuristic algorithm is applied to remove the unnecessary material at locations where it is not needed. In the second phase, the optimization is carried out using genetic algorithm for optimal ply orientation to tailor the directional dependent properties such as strength and stiffness. From the numerical experiments, they have concluded that the proposed approaches are effective in reducing the weight of composite laminate structures and finally, they have emphasized the application of the proposed algorithm for direct engineering application.

Kripka (2004) has made an effort on the application of Simulated Annealing algorithm to find the minimum weight of truss structures. The optimization problem was formulated as a constrained optimization problem by treating the cross-sectional areas of truss members as discrete design variables. The stress and displacement constraints were incorporated in the formulation of the design problem. The viability of the proposed model has been demonstrated through a standard benchmark problem in the field of structural optimization and resulted i.e. minimal weight design was compared with those obtained using other approaches like GA, Branch and Bound method, Difference Quotient method, Improved Penalty Function Method and SA.

Rajasekaran et al (2004) have adopted Evolution Strategies (ESs) and Functional Network (FN) for minimizing the weight of space truss by treating the cross-sectional areas of the members as discrete. They have employed Formex algebra of Formian software for creating the input data.

Lin and Lee (2004) have made an attempt on the application of improved GA for optimal stacking sequence of laminated composite structures. In their study they have incorporated a local search improvement
technique into a standard GA in view of reducing the huge computational time of GA. Based on their numerical experiments, they have concluded that the improved GA produces good quality solution compared to a standard GA in a relatively short time.

Bland (2001) has proposed a blended scheme of Ant Colony Optimization and Tabu search called, ACOTS for minimizing the weight of space truss (i.e. a 25-bar truss), a standard benchmark problem in the field of structural optimization. He is the first investigator to extend the Ant Colony Optimization for structural application. He has treated the optimization problem as a constrained optimization problem by treating the discrete cross-sectional areas as design variables. He has compared the minimum weight of space truss obtained using ACOTS with those of other heuristics like GA. He has concluded that ACOTS is technically a viable optimization tool for discrete structural optimization. Finally he has brought out the major limitation of ACO that it requires inherently long computational time when compared to other optimization tools like GA and SA.

Camp and Bichon (2004) have presented a modified form of original ACO algorithm for minimizing the weight of space truss. They have treated the weight minimization problem as a constrained optimization problem. They have transformed the problem into a modified TSP where the network of TSP reflects the structural topology and the length of TSP tour as the weight of the structure. Further they have compared the minimum weight of space truss obtained for 10-, 25- and 72-bar space trusses using modified ACO algorithm with those obtained using other optimization techniques. They have compared the potential advantages of ACO with that of GA and discussed the several unique characteristics of ACO.
Camp et al. (2005) have presented a modified form of original ACO algorithm for minimizing the weight of steel frames. They have treated the weight minimization problem as a constrained optimization problem. They have transformed the problem of weight minimization of steel frame into a modified TSP where the network of TSP reflects the structural topology and the length of TSP tour as the weight of the structure. They have demonstrated the viability of the proposed ant based algorithm by comparing the optimal design obtained using ACO with those obtained using other approaches like GA and other classical approaches.

2.4 NEED FOR THE PRESENT WORK

A critical review of the literature shows that majority of the structural optimization problems have been solved using Genetic Algorithm, Simulated Annealing and Tabu Search. Very limited work has been done on the use of ACO for structural optimization. For an efficient optimization technique, the algorithm should be capable of generating better quality solutions at each discrete time step and should generate the global optimum or near optimal solution in a reasonable amount of computational time. But from the literature review it is observed that most of the algorithms used for structural applications have some common limitations such as

- Enormous computation time
- Large number of functional evaluations
- Algorithm termination at sub-optimal points and
- Premature convergence to an infeasible solution

Therefore, a new algorithm is proposed namely “Domain-Based Multiple Ant Colony Optimization (DB-MACO)” algorithm for structural optimization to address the above issues.
2.5 SUMMARY

In this chapter review of literature has been done in the field of optimization using ant based algorithms, simulated annealing, tabu search and genetic algorithm. Some common drawbacks are listed and the need for the present work has been discussed. In the next chapter, the fundamental concepts of some of the non-traditional optimization techniques are explained.