8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

MULTIOBJECTIVE OPTIMUM DESIGN OF METALLIC STRUCTURAL FRAMES CONSIDERING THE CONSTRAINED WEIGHT AND THE NUMBER OF DIFFERENT CROSS-SECTION TYPES USING DENSEA

***D. Greiner, J.M. Emperador, G. Winter and B. Galván**

Institute of Intelligent Systems and Numerical Applications in Engineering (SIANI)
University of Las Palmas de Gran Canaria, 35017, Spain
{dgreiner, jemperador}@iusiani.ulpgc.es, {gabw, bgalvan}@step.es

Key Words: *Evolutionary Multiobjective Algorithms, Structural Optimization, Frames.*

ABSTRACT

Evolutionary multiobjective algorithms have been a successful stochastic tool for engineering global optimum design since the final nineties. In a context of conflicting objectives where improving one of them implies the worsening of others, evolutionary multiobjective algorithms allow to obtain in one single run a set of non-dominated solutions in the sense of Pareto criterion. Among their fields of application is also computational solid mechanics.

Being structural engineering one of the pioneer engineering fields where optimum design using evolutionary algorithms was applied since the middle eighties, in this work the resolution of the optimum design multiobjective structural problem consisting in the simultaneous minimization of the constrained weight and the minimization of the number of different cross-section types in metallic frames structures is handled.
The first objective (constrained weight) is directly related to the minimization of the structure raw material costs. In order to guarantee the structural mission compliance, different constraints are taken into account, including maximum allowable stresses (here limited to the elastic range and considering the Von Misses criterion), displacements in certain nodes and also the buckling effect. These constraint violations are considered in the first fitness function using a penalty function scheme and they are evaluated using the direct stiffness method with inverse Cuthill-McKee reordering.
The second objective (number of different cross-section types) is related with constructive costs and recently also with the life cost cycle. Its relevance grows with the structural size.

This multiobjective optimization problem has a discrete search space both in terms of functional and variable ranges, therefore, being evolutionary algorithms suitable for its resolution. Moreover, their capability to obtain global optima surpassing local ones due to the population search they perform is one main advantage over other classical optimization methods.
Several structural frame test cases of different size extracted from the recent literature

are compared, including the consideration of sideways buckling and their own gravitational load. Real discrete cross-section types belonging to the standard European IPE and HEB cross-section types are the variables which code the candidate chromosomes. So, the optimum solution set found by the multiobjective evolutionary algorithm represents practical structures which solve a real engineering design problem: each point is the structural design of minimum weight corresponding to a number of different cross-section types. The chromosome codification is done using the standard binary reflected gray code.

Among the evolutionary multiobjective algorithms, those belonging to the so called second generation [1] are the most efficient. They are mainly characterized by the use of elitism and the growth of parameter independence compared versus the first generation algorithms. Here, the DENSEA algorithm [3, 4] is compared with a well-known second generation algorithm in the state of the art, the Non-dominated Sorting Genetic Algorithm-II (NSGA-II [2]). Both are applied to the previous formulated solid mechanics optimum design problem. The comparative analysis handles also different mutation rates. Due to the stochastic nature of evolutionary algorithms, thirty executions of each case were run and a statistical analysis considering mean and variance of certain metrics is needed to compare their relative performance.
DENSEA is designed specially to take profit of the characteristics of the solid mechanics problem handled which include a reduced discrete functional search space in one of the objective functions, because the non-dominated front set is composed of isolated points and also the number of designs belonging to this set is low compared with the standard population size used in evolutionary algorithms. So, in this discrete search space problem with low number of optimum solutions a proper treatment of population diversity is a key to success.

Results show a faster convergence velocity and better quality of the final fronts achieved by DENSEA compared versus the other multiobjective evolutionary algorithm in the structural test cases handled.

REFERENCES

[1] C. Coello Coello, "Evolutionary multi-objective optimization: A historical view of the field", *IEEE Computational Intelligence Magazine*, Vol. **1**(1), pp. 28-36 (2006).

[2] K. Deb, A. Pratap, S. Agrawal, T. Meyarivan, "A fast and elitist multiobjective genetic algorithm NSGAII", *IEEE Transactions on Evolutionary Computation,* Vol. **6**(2), pp. 182-197, (2002).

[3] D. Greiner, J.M. Emperador, G. Winter, "Enhancing the multiobjective optimum design of structural trusses with evolutionary algorithms using DENSEA." *44th AIAA (*American Institute of Aeronautics and Astronautics*) Aerospace Sciences Meeting and Exhibit*, paper AIAA-2006-1474, (2006).

[4] D. Greiner, J.M. Emperador, G. Winter, B. Galván "Improving Computational Mechanics Optimum Design Using Helper Objectives: An Application in Frame Bar Structures", *Lecture Notes in Computer Science,* (Evolutionary Multi-Criterion Optimization), Vol. 4403, pp. 575-589, (2007).