5th International Conference on Reliable Engineering Computing (REC2012)
June 13-15, 2012
Brno, Czech Republic, EU

Reliability-based Optimization: An Overview and Recent Advances

G.I. Schuëller[1] and M.A. Valdebenito[2]

[1] Professor, Institute of Engineering Mechanics, University of Innsbruck, Technikerstraße 13, A-6020, Innsbruck, Austria, EU, e-mail: Mechanik@uibk.ac.at (presenter).
[2]Assistant Professor, Departamento de Obras Civiles, Universidad Tecnica Federico Santa Maria, Av. España 1680, Valparaiso, Chile.

Keywords: Uncertainties, structural reliability, advanced simulation techniques, reliability-based optimization, reliability sensitivity, optimal maintenance scheduling.

Abstract

Engineering aims at designing systems that can fulfill prescribed performance objectives within a certain life time. For example, consider the design of a metallic structure subject to cyclic loading. In this particular case, a relevant design objective would be ensuring that fatigue damage leads neither to loss of serviceability nor to collapse. This design objective may be achieved, e.g. by sizing structural members such that stresses are below a certain threshold or by scheduling appropriate maintenance activities. As resources for constructing and maintaining any structure are always scarce, the final design of the target system should not only comply with prescribed performance objectives but also its life time cost should be as economic as possible. In view of this last statement, it is clear that the design task may be interpreted as the solution of an optimization problem, i.e. the objective is to minimize overall costs, while ensuring that the structural performance is within acceptable limits [1].

Although the formulation of the design problem within the context of optimization is certainly advantageous, there is a major issue present in almost all practical design situations: several parameters which are relevant for design cannot be quantified by precise, deterministic values, as they are inherently uncertain. Typical examples of these parameters include loadings, member sizes, material properties, etc. The uncertainties in these parameters affect the structural response. In consequence, the behavior of the structure will be uncertain as well. Therefore, the presence of these uncertainties should be reflected in the design process of a system. A possible means to quantify the effects of uncertainty in the system's response is resorting to probability concepts, as they allow calculating *reliability*, i.e. the probability that the performance objectives will be fulfilled [2]. The consideration of the effects of uncertainty by means of reliability within the design process (formulated as an optimization problem) is known in the literature as reliability-based optimization (RBO) [3].

Although RBO constitutes a most powerful tool for design in engineering, its application to problems of engineering interest has remained limited in the past due to high numerical costs involved in its solution. These high costs are due to repeated evaluation of structural response (by means of numerical methods such as finite elements) required for solving problems of optimization and structural reliability. Nonetheless, in recent years several new methodologies have been developed which render involved RBO problems tractable. Within this context, the objective of this lecture is presenting some

of the most recently developed tools for RBO. The focus is on two aspects. The first one comprises the application of advanced simulation techniques, which have opened the possibility for assessing structural reliability for large structures [4], particularly for problems involving a large number of uncertain parameters (in the order of thousands) as well as a large number of failure criteria. The second aspect is the efficient assessment of reliability sensitivity [5], i.e. how much does the structural reliability vary due to a perturbation in variables that are controlled by the designer. Theoretical as well as practical aspects on the application of tools for solving RBO problems are discussed. Case studies are also analyzed in order to show the applicability and efficiency of the tools introduced. Special emphasis is given to applications involving optimal structural design for stochastic linear and nonlinear dynamics [5,6] as well as optimal maintenance scheduling for fatigue-prone structures [7].

References

[1] R.T. Haftka and Z. Gürdal. Elements of Structural Optimization. Kluwer, 3rd edition, 1992.

[2] A.M. Freudenthal. Safety and the probability of structural failure. *ASCE Transactions*, 121:1337-1397, 1956.

[3] I. Enevoldsen and J.D. Sørensen. Reliability-based optimization of series systems of parallel systems. Journal of Structural Engineering, 119(4):1069–1084, 1993.

[4] G. I. Schuëller, H. J. Pradlwarter, J.L. Beck, S.K. Au, L.S. Katafygiotis and R. Ghanem. Benchmark study on reliability estimation in higher dimensions of structural systems - An overview. In C. Soize and G. I. Schuëller, editors, Structural Dynamics EURODYN 2005 - Proceedings of the 6th International Conference on Structural Dynamics, pages 717-722, Paris, France, September 4-7 2005. Millpress, Rotterdam.

[5] M.A. Valdebenito and G.I. Schuëller. Efficient strategies for reliability-based optimization involving non linear, dynamical structures. Computers & Structures, 89(19-20):1797-1811, 2011.

[6] M.A. Valdebenito, H.A. Jensen, G.I. Schuëller, and F.E. Caro. Reliability sensitivity estimation of linear systems under stochastic excitation. Computers & Structures, 92-93:257-268, 2012.

[7] P. Beaurepaire, M.A. Valdebenito, H.A. Jensen, and G.I. Schuëller. Reliability-based optimization of maintenance scheduling of mechanical components under fatigue. Computer Methods in Applied Mechanics and Engineering, 221-222:24-40, 2012.