A Brief Overview of Global-local Analysis in Structural Design Problems

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***Abstract*—Structural design problems considering strength, buckling, and damage could be computationally demanding. In order to overcome the computational challenge, the global-local approach has been developed. In this method, first, an approximate analysis of the entire structure is performed. Following this, a smaller area of interest in the structure is selected, and a detailed analysis is performed considering boundary conditions from the global analysis. This article provides a brief overview of such global-local techniques used by different researchers for structural design.**

***Index Terms*—Structural Design, Buckling, Global-Local Analysis**

Design of structural components are constrained optimization problems which requires analysis and constraint determination related to strength and buckling [1]–[20]. Structures subjected to compressive load can fail due to buckling before reaching the compressive strength limits. Once the structure buckles, its deformed configuration changes consistently as well as its stiffness reduces. This means that the behavior of the structure is nonlinear or equivalently that the stiffness of the structure depends on the deformed configuration. This type of behavior of structures is known as post-buckling behavior.

Generally, experimental tests related to the instability of structures (i.e., flat panels) are performed by fully constraining two edges of the structure whereas the other two edges may be unsupported or supported [21]. The structure is then end-loaded under compressive force. Actually, this is the configuration used for the measure of the residual strength of a composite structure after an impact (or Compression after Impact tests).

Pietropaoli and Riccio [21] conducted buckling and post-buckling analysis of composite stiffened panels using Finite Element Analysis. Numerical tools like Finite Element Method provide a very general and flexible modeling approach. However, including damage into the composite structure increases the degree of complexity of the finite element models and requires enormous computational time and storage space. As a solution to this limitation, the global-local analysis technique could be used. The global-local analysis is a technique that helps in reducing the high computational complexity of structural problems without affecting the accuracy of the results [22]. During the last four decades, this technique has gained popularity among researchers for solving complex structural problems. The procedure starts by an approximate analysis of the entire structure. Then, a smaller area of interest in the structure is selected (for example the damage location) and it is called local region or local zone. A detailed analysis is performed to this local zone considering the boundary conditions resulting from the output of the global analysis. An extensive review of the global-local analysis technique has been provided by Kapania, et al. [23] and Haryadi, et al. [24]. A. K. Noor [25] has applied the global/local technique for predicting nonlinear and post-buckling responses of stiffened and unstiffened composite panels. Global-local FEM approaches are generally used in several technical applications such as managing 3-D stress analysis in the case of bonded joints, computing J-Integrals in Fracture Mechanics problems [26], or obtaining Stress Intensity Factors (SIFs) in corners or fillets [24], [27]–[29].

Mote Jr. [30] is one of the first few researchers to apply the global-local method to solve the structural problems. He developed a combined global and local dependent variable representation, which couples the traditional finite element and Ritz methods. He illustrated the method by solving a beam and a plate vibration problem. Zienkiewicz, et al. [31] and Belytschko, et al. [32] used a combination of finite element and boundary element methods for global-local analysis. Belytschko, et al. [33] developed a methodology for enhancing the accuracy of finite element solutions of problems with higher gradients by superimposing the spectral approximation on subdomains. Many researchers have applied the global/local computational approaches successfully for composite structures [34]–[37]. In most of these works, the structural zooming was performed in order to obtain a higher level of accuracy in the stress state at the selected regions and the characterization of the different damage mechanisms that can lead to the structural collapse. Ransom and Knight [34] applied the global/local technique to composite panels. In their approach, they used spline interpolation functions to determine the boundary condition from the output of the global analysis and use it in the local analysis. Reinoso, et al. [37] applied global/local techniques to model the response of composite structures including degradation process at the interfaces.

Jara-Almonte and Knight [38] described a new approach of modeling the sub-regions of interest. They specified the stiffness and force from the whole model solution at the nodes of the boundary of the sub-region. Hirai, et al. [39] found out stress concentration factor around a circular hole in a rectangular plate under in-plane load using a finite element zooming technique. This method involves several zooming steps. In each zooming step, the zooming area becomes smaller and displacements at the boundaries are taken from the previous zooming step. Multiple zooming steps were proposed for a better accuracy of the result. However, this model is not always satisfactory because all the previous steps are needed to go to a new step [23].

Kapania, et al. [23] used a simple and accurate global-local method for stress analysis of stepped, simply supported isotropic and composite plates under the action of a static uniform transverse pressure. In the first step, they determined the response of the plate in the absence of the hole. This solution was augmented using a perturbation function to account for the presence of the hole. In the second step, a small area around the hole was analyzed using the finite element method for accurate analysis around the hole. Displacements and rotational boundary conditions for the local region were obtained from the Ritz method used in the first step. Subsequently, Haryadi, et al. [24] used this approach for the analysis of a composite plate with a crack under the action of a uniform, transverse static pressure. Islam and Kapania [40] discussed the efficiency and accuracy of the global/local finite element method applied to a curvilinearly stiffened panel with cracks.

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