



Article

On Hierarchical Applications of Finite Element Methods and Classical Applied Mechanics Approaches for Complex Structures

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Abstract: In this paper, hierarchical studies based on both analytical and computational approaches have been employed to validate and improve current structural designs of mud holding tanks for hydraulic fracturing in petroleum industries. Through detailed comparisons at different levels of approximations for both real world complex structural design problem and a simplified stiffened plate with extreme geometrical aspect ratios, proper design procedures have been reiterated and validated. It is highly recommended that low-dimensional structures with emphasis on classical mechanics principles should be considered before full-fledged three-dimensional computational analyses. Both Castigliano's Theorems and Galerkin methods are utilized along with simulation packages such as ADINA and Solidworks. The hierarchical approximation procedures reemphasize important subjects such as planes and shells, strength of materials, structural mechanics, asymptotic and perturbation analysis no longer required in some engineering programs, yet often necessary for the study of complex three-dimensional structural systems.

Keywords: finite element method; hierarchical; stiffener; buckling; multi-scale modeling



Citation: Wang, S.; Ndip-Agbor, E.; Atamenwan, E. On Hierarchical Applications of Finite Element Methods and Classical Applied Mechanics Approaches for Complex Structures. *Appl. Mech.* **2022**, *3*, 464–480. <https://doi.org/10.3390/applmech3020027>

Received: 22 March 2022

Accepted: 15 April 2022

Published: 18 April 2022

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1. Introduction

In today's engineering practice, analyses of very complex systems are frequently studied based on various finite element methods (FEM) and computational fluid dynamics (CFD) tools. The sophistication of these simulation packages and their direct connections with solid modeling and engineering graphics tools have inadvertently left false impressions among design engineers that the fundamentals of solid and fluid mechanics are no longer needed. In fact, some of the design engineers tend to utilize simulation packages right at the beginning stage of the design process at which the entire system and its geometries and configurations are still not finalized. As a consequence, the intricate design details and specifics which are not finalized will be entangled with the complication of meshing and multi-scale issues for both FEM and CFD analyses. In a way, this is very similar to applying high resolution or magnification lenses during preliminary search within a fairly large area, which is obviously very ineffective, inefficient, and wasteful with respect to both time and financial resources.

Wichita Tank Manufacturing LTD presented the McCoy School of Engineering with a design concern with respect to their 500 fluid barrel (BBL) holding tanks for hydraulic fracturing, as shown in Figure 1. In the United States of America, most fluid barrel apart from oil barrel has the following conversion ratio, namely, 1 BBL is equivalent to 119 liters (L) or 31.5 gallons. Initially, these tanks were designed to hold up to 15,750 gallons of water. While it is empty, the tank will be transported through highway systems to and from different locations. The problem is to determine whether or not it is safe to hold

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