Large CAD assembly design analysis using Sefea (Strain-Enriched FEA) and MLS (Moving Least Squares) formulation

Yu Hou[1], H. Theodore Lin[2], Chang-Pin Pan[3]

[1]Suzhou AMPS Technologies Company, LTD, Jiangsu, China
[2]AMPS Technologies Company, Pittsburgh, PA, USA
[3]Dept of Construction Engineering, National Taiwan University of Science and Technology, Taiwan

Abstract

Since the late 80's, most industrial designs have been performed using computer-aided-design (CAD) software and are commonly subjected to stress, thermal, electrical, flow, or multiphysics design analyses. These design analyses mainly aim to reduce prototyping cycles, improve understanding of operational behavior, identify critical regions/parts in early design cycles, serve as forensic simulations to troubleshoot failure in field applications, etc.

Finite element analysis (FEA) is one of the mostly commonly applied tools in these design analyses due to its flexibility in geometric modeling and the extensively validated linear/nonlinear material modeling capability. In the late 90's, most design analyses were for an individual part's shape, integrity, and efficiency. However, in the last decade, as the analysis tools become more capable and computer power grows, large scale assembly design analyses are becoming more common.

For assembly design analyses, many realistic parts may have intentional gaps or overlapping for welding or thermal expansion/shrinkage, or there may be other unintentional openings/interference due to CAD software tolerance issues. Such issues have been known in the CAD/CAE industry as "dirty geometry" handling. Using traditional FEA products will require meshing these parts as one connected piece for the underlying physics to behave properly across the part boundary. Nevertheless, even the most precise solid modeling kernel may not be able to precisely unite these parts as one integrated assembly.

In this paper, we address such large assembly analysis issues by reviewing the available methods and the advantages/disadvantages of each. We focus on the solution algorithm rather than the mathematical mesh healing and geometry adaption methods.

We first present the Strain-Enriched FEA (Sefea) formulation [1] extended from the enriched finite element research. The low order Sefea tetrahedron elements can be generated automatically and can achieve the accuracy of traditional 2nd order finite elements but have better equation conditioning for numerical robustness for nonlinear and large deformation dynamic analysis. Since Sefea uses only 1/5 or fewer equations than traditional FEA for the same level of accuracy, it is suitable for large scale CAD assembly analysis.

To accommodate such gaps or overlapping of the dirty geometry, we propose the moving least squares (MLS)[2][3] general constraint formulation derived from mesh-free method to ensure energy balance across the gap of the separated parts.

Using the Sefea and MLS methods, we further discuss automatic spatial recognition of the separated regions, treatment of the intended gap for contact analysis and the unintended overlap and opening gluing, and automatic MLS equation setup. We present several large scale design assemblies as examples of the automated, accurate analysis achieved with these methods.

Keywords: Finite Element, Enriched Finite Element, Moving Least Squares, CAD, Multiphysics

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