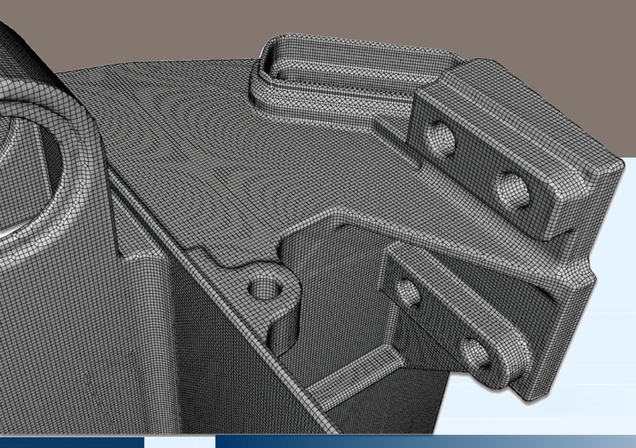
SAND2013-3115P

Sculpt: A new tool for automatic parallel hex meshing



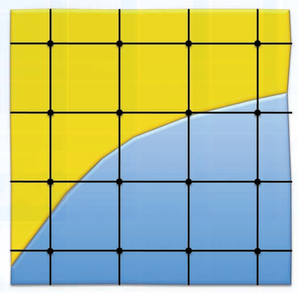
Steven J. Owen, Org. 1543 Simulation Modeling Sciences

Sculpt is a parallel code that will generate an all-hex mesh from an STL (triangle) representation. Avoiding the traditional complex decomposition strategies often needed for hex meshing, Sculpt can automatically mesh complex geometries with no human interaction. It shares a code-base with the serial CUBIT Geometry and Meshing Toolkit, but has its own stand-alone parallel executable. It can be run from within CUBIT or from a unix command line on a distributed computing environment.

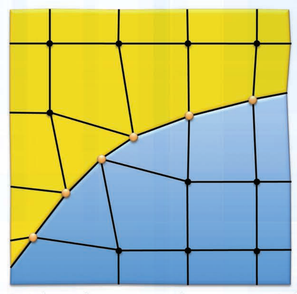
Objectives

Fast, Scalable Automatic Hexahedral Meshing for Complex CAD Assemblies

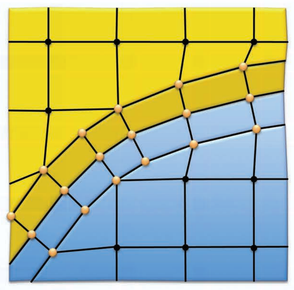
1. *Scalability to billions of elements and thousands of processors*
2. *Eliminate current manual processes for geometry decomposition for hex meshing*
3. *Avoid tedious geometry cleanup procedures required by current meshing software.*



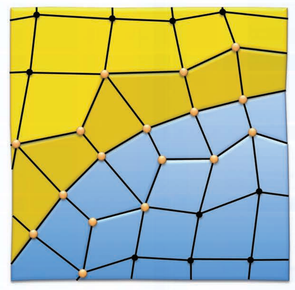
Initial overlay grid



Grid nodes moved to material interface



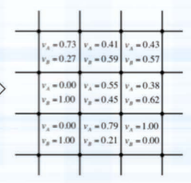
Hex layers inserted at interfaces



Smoothing performed

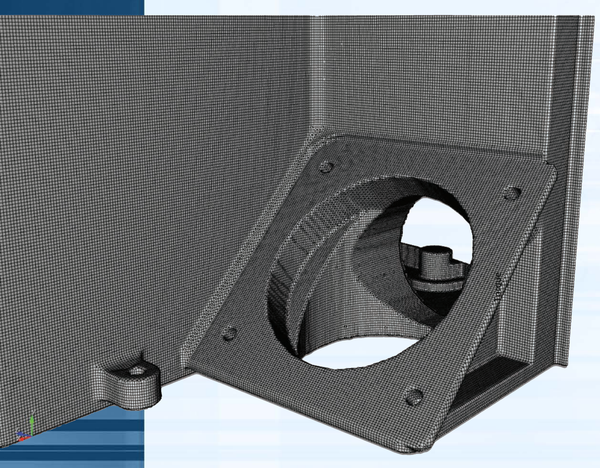
Sculpt Overlay Grid Procedure

STL Geometry Description



Volume Fraction Data

All-hex mesh

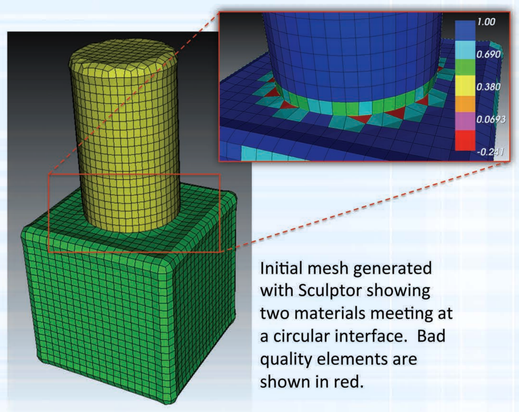


The Sculpt tool first converts the STL triangles into a volume fraction representation defined on a Cartesian grid. The density of the grid is defined by the user and becomes the basis for the all-hex mesh. The geometric boundary is captured by recovering surfaces from the volume fraction information. Layers of hexes are inserted and smoothing performed to improve mesh quality. The result is a set of exodus files (1 per processor) that can be used as-is or joined using the seacas epu code. Sculpt is also used as an in-situ meshing solution for Alegra, where input can be a standard diatom description.

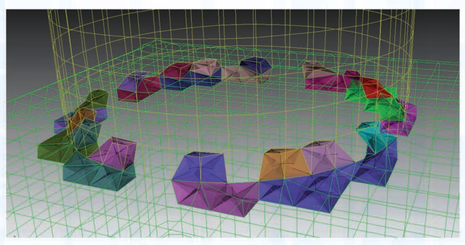
16 Processor Decomposition

Tackling Multiple Material Interfaces

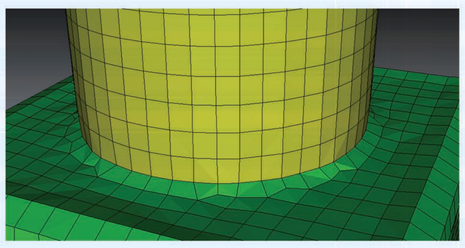
Using the overlay grid method from Sculpt, poor quality can result where nodes are constrained to an interpolated curve definition at material interfaces.



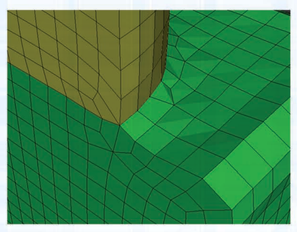
Initial mesh generated with Sculptor showing two materials meeting at a circular interface. Bad quality elements are shown in red.



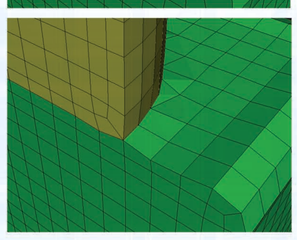
Solution 1: Hex-Dominant: Replace poor quality hexes with tets. Sidesets/Nodesets to describe hex-tet constraints are established.



Solution 2: Pillowing: A layer of hexes is inserted at interfaces to locally improve quality at curves.



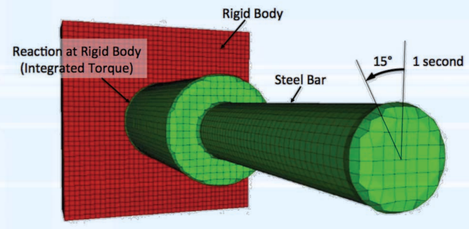
Cut-away of mesh at interface before pillowing operation



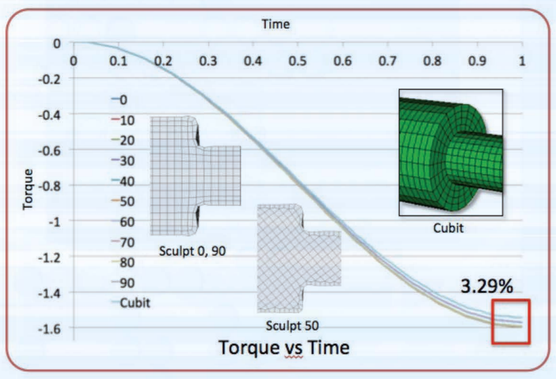
Same mesh following pillow insertion operation

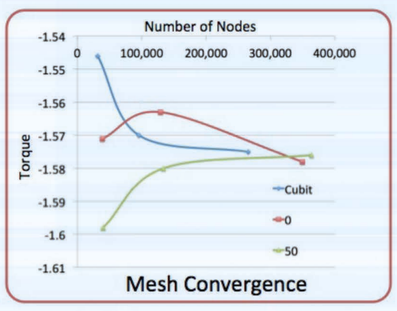
Accuracy of Sculpt Meshes using Adagio

Results from a Cubit-generated mesh were compared with a series of Sculpt meshes where the base Cartesian grid was oriented at 10 degree intervals. Results showed integrated torque measured at a rigid body was within 3.29% for equivalent degrees of freedom for Sculpt and Cubit meshes.

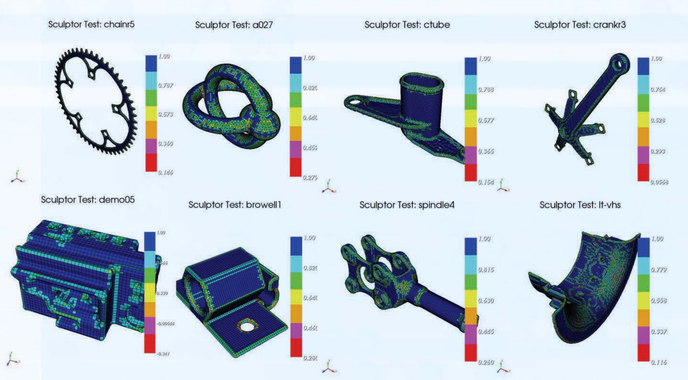


Quasistatic simulation of a steel bar rotated through 15 degrees over 1 second. Reaction at the rigid body was measured.





Test-Driven Development



A series of 60 CAD models is used to validate the Sculpt procedures. Successful generation of computable meshes on these sample models is one measure of success.

Next Steps

1. ***Mesh Adaptation:*** *Overlay grid cell size should adapt to capture local feature size using hex refinement operations.*
2. ***Degenerate Hex Elements:*** *Investigate generation and use of degenerate elements (pyramid, penta, knife, …) in poor quality situations.*
3. ***Improved Geometry Sensitivity:*** *Use initial CAD topology information to drive hex layer insertion and mesh improvement operations to better represent geometry.*
4. ***Scalability:*** *Validation of Sculpt on massively parallel machines. (100s of cores, 1000s of components/parts, 500M to 1 Billion elements)*

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