Meshing For Crack Propagation Simulation: Problems....

... from Within ... ...and Without

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With a lot of help from his friends in the Cornell Fracture Group
And
ASP/ITR Project
Outline of Presentation

• The crack propagation problem:
  Definitely evolutionary geometry, but need it be evolutionary meshing?

• The problem within: examples of current simulation capability. And shortcomings.

• The problem without:
  The meshfree methods are here, and more coming! Are they just a challenge, or a revolution?
Crack Propagation is a Problem of National Significance

An aging (>40 years old) military aircraft dies…
Predicted Curvilinear Fatigue Crack Growth:
Adaptive Remeshing for Shell FEM
Early Damage Tolerance Testing on B-707 Fuselage

Single Bay Flaps
An aging (>21 years old) civilian aircraft kills…

Fatigue crack growth coupled with corrosion in lap joints in skin

Ductile Tearing
Aging Dams are Cracking

Fontana Dam
North Carolina, USA

Crack on downstream face of a gravity dam?
NY State Thruway, I90, Bridge Collapse
Let’s Dissect The Meshing Process with a Simple 2D Problem
Requirements for an Advancing-Front-Based 3D Mesher for Crack Problems

• Produce well-shaped elements
  ✓ Of course

• Conform to an existing, triangular surface mesh on region boundary
  ✓ Especially in small regions around extending crack front
  ✓ Allows fast, local remeshing
  ✓ Minimize information transfer between old and new meshes

• Transition well between regions with elements of highly varying size
  ✓ As much as 2 orders of magnitude difference in crack problems

• Accommodate geometrically coincident, arbitrarily shaped crack surfaces
  ✓ Discriminate between nodes on opposite crack faces
Mesh Model of SH 60 Seahawk
Power Transmission Spiral Bevel Gear
Initial Flaw Size and Location

Problem Demands

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<th>214,000 - 327,000</th>
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Comparison: Simulated versus Observed

Crack Trace on the Face of Tooth
Comparison: Simulated versus Observed Fracture Surfaces
Comparison: Simulated versus Observed Crack Trace on Gear Hub
Mesh Detail on Tooth Surface

Initial Flaw/Mesh

Later Stage of Simulation
An OpenDX and SQL Server-Based Mesh Analysis Tool
The “Nanotechnology” Revolution is Creating Interesting Meshing Demands

2D Representations of Crack Initiation in a Metallic Polycrystal
Things Get Tough in 3D

- 50 µm cube
- Only 100 Grains
- 6,271,419 DOF
- 1,519,816 10-noded tets
Mesh Analysis and Improvement Tool Even More Necessary

Real time interaction through SQL Server

Fast graphical and numerical feedback

Fast numerical evaluation of quality improvement

Real time drag offending node
Problems from Without:
The Meshless Methods Challenge
or
Is It a Revolution?

Money, interest, and PhD’s are flowing to meshless methods. Why? Can they:

• Solve problems that can’t be solved with meshed methods?

• For problems solvable with meshed methods, can meshless methods solve them:
  ➢ More efficiently?
  ➢ With better physics and mechanics?
Is This the BIG LIE, or ....

“...The development of a technique that does not require the generation of a mesh for complicated 3D domains is still very appealing. The problem of mesh generation is that the time remains unbounded, even using the most sophisticated mesh-generator...”

Sessions at 5th World Conference on Computational Mechanics on Meshless Methods: 8
Mesh Generation: 0

BCM—Boundary Cloud Method

MFEM—Meshless Finite Element Method

MWLSM—Meshless Weighted Least-Squares Method

SPH—Smooth Particle Hydrodynamics

EIBM—Extended Immersed Boundary Method

FCM—Finite Cover Method

AMFDM—Adaptive Meshless Finite Difference Method

EFG—Element Free Galerkin

DPD—Dual Particle Dynamics

MFS—Method of Finite Spheres
Summary

For meshed approach with explicit representation of crack geometry:

• Work underway on guaranteed-quality, Delaunay-based, 3D, mesher, with ideal crack front features for simulation of crack propagation: DMESH

• Ditto, minus the guarantees, with an advancing-front-based approach: JMesh

• Both benefiting from a suite of quality assessment/improvement tools using a SQL Server/ OpenDX basis.

Meshfree approaches with/out explicit representation of crack geometry:

• They are here, in droves!

• Are they a revolution, or just a challenge?