Computer simulation of blasting with precise initiation

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Better blasting results...

• Blasting = to fragment rock into suitable dimensions

• Improved fragmentation results in:
  – Reduced costs for blasting
  – Reduced costs for transportation of blasted rock
  – Reduced emissions
  – Reductions in energy consumption during crushing & grinding
  – Improved metal recovery
Background and hypothesis (I)

- Electronic blasting caps
  => short delay times (microseconds)
- Short delay times
  => shock waves interacting between holes
- Hypothesis (Rossmanith, 2002):
  *Fragmentation is improved in areas between blast holes where the tensile waves meet, overlap and interact*
Tensile wave superposition
Tensile wave superposition!
Background and hypothesis (II)

- Practical experiences show that improved fragmentation, throw, swelling, and diggability, can be achieved through short delay times

- Quantitative computational models that describe this phenomenon are lacking
Project approach

• Develop a methodology for dynamic numerical (computer) simulations of blasting
• Full-scale field tests using electronic blasting caps
• Numerical analysis of laboratory (model scale) tests and full-scale field tests
Computer simulation of blasting

• Challenges:
  – Representative material model for rock (DIANE material)
  – Replicate rock response to very large pressures and subsequent damage
  – Material model for the explosives
  – High resolution of numerical model

This is at – or beyond – the current state-of-the-art!
Computer simulation of blasting

- **Methodology:**
  - *LS-DYNA* computer code
  - Euler and Lagrange element formulation (in combination)
  - RHT (Riedel-Hiermaier-Thoma) material model
  - Algorithm for interpreting fragmentation based on calculated damage (yield)
Computer simulation of blasting

- **Dual hole model**
  - Subset of open pit bench blast
  - 20 million elements; 50 mm resolution
  - 15 ms simulation time; 28 h computer time
• **Parametric study**
  – Blast initiation / delay time
  – Decreased amount of explosives
  – Increased blasthole spacing
Crack pattern
Fragmentation results

Improved fragmentation

- Ref 0 ms
- 1.5 ms
- 5 ms
- Large
- 8 m
- 8m and 11 m

Rock fragment area [m²]

Accumulated area [-]
Effect of hole spacing

- 8.7 m hole spacing
- 12.3 m hole spacing
Some conclusions...

- Developed methodology found functional even for very large LS-DYNA models
- Small, and only local, effects of interacting stress waves
- Hole spacing and amount of explosives had much larger effect on fragmentation
- Highest amount of fragmentation found for a long delay time in which the primary stress wave had passed the second blast hole (i.e., no wave superposition)!
Continued project work (I)

- Simulation of laboratory model tests
  - comparison of simulation and laboratory data

- Full-scale simulations
  - open pit blasting
  - sublevel caving blasting
Continued project work (II)

- Full-scale field tests
  - practical tests at the Aitik mine with different delay times
  - follow-up of fragmentation, swelling, crusher power consumption, etc.
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