Microwave Induced Stress in Rocks

A Numerical Approach

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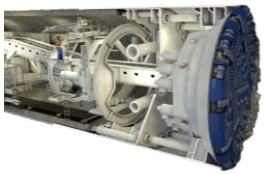
Background

Tunnel boring machines: Currently, there is great challenge for TBM on hard or abrasive rocks.

- High cutter wear
- Low efficiency



TBM in operation

Microwave can induce high temperature in the rock in very short amount of time. Which create high thermal gradient and high thermal stress.

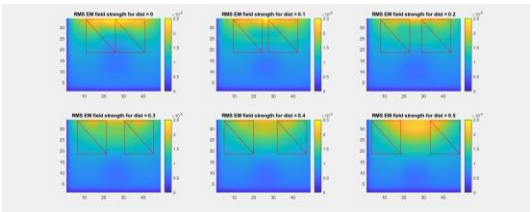
Microwave pre-treatment offers promising improvements to the process

- High cutter wear
- Low efficiency

Article	Experimental measure	Results	Authors
3D Numerical Study on Microwave Induced Stress in Rocks	Used 3D Coupled multi-physics modeling to simulate the stress	Microwave treatment has the potential to induce high stresses which can eventually lead to damage formation.	Michael T. , Ronald M, Philipp H , Friedemar K , Thomas A
Thermal stress FEM analysis of rock with microwave energy	Used FEM to simulate Cracking process around a single crystal	The thermal expansion coefficient of microwave-absorbing minerals plays a critical role in producing thermal stress	Yicai W, Nenad D

Simulation Setup

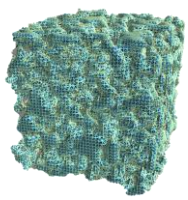
Simple geometry



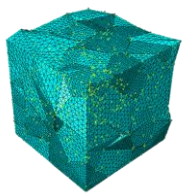
The red square in the figures are square particles. The graph shows that the distribution of the particle greatly affects penetration and power distribution of the EM field.

Complex geometry

- Complex geometry that are more closely resemble the real life situation
- The geometry is generated using Python **Voronoi** Algorithm.
- The geometry is then transferred to Abaqus using **Convex Hull** algorithm.
- In the figure shown. The solid parts are the microwave-absorbing particles and the transparent parts are the microwave-transparent matrix.
- The algorithm allows the ratio of the particles and density of the particles to be customized.



3d microstructure of rocks generated by Voronoi Algorithm.

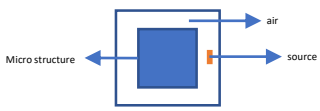


Mesh generated according to Voronoi geometry.

Simulation Methodology

Electromagnetic field simulation

EM field is generated and propagated in the software MEEP.
The source of the EM field is a simple plane source that generates Z axis polarized wave.



MEEP simulation layout

3D wave EM-wave visualization

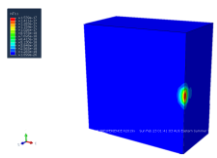
Constitutional model of the rock

During this project, different constitutional model from the Abaqus is also explored to improve the accuracy of the simulation. The models include:

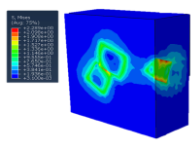
1. Drucker Prager Plasticity
2. Mohr Coulomb Plasticity

The results of this models are presented.

Thermal and structure field simulation



EM induced heat in rock sample

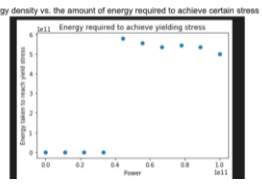


Heat induced stress in rock sample

Results

In conclusion, this project mainly focused on the feasibility study of the use of microwave in assisting breaking of the rocks. Though analysis of the result, we can conclude that

1. The rock breakage is more efficient with high power and short pulse microwave.
2. The absorption crystal heat up first, which form high temperature gradient with the surrounding matrix.
3. The penetration of the microwave depends on the power of the microwave, the frequency of the microwave and the constitution of the rock.



Results analyzed