A THERMO ELASTIC MODEL FOR MICROWAVE ABLATION OF CONCRETE

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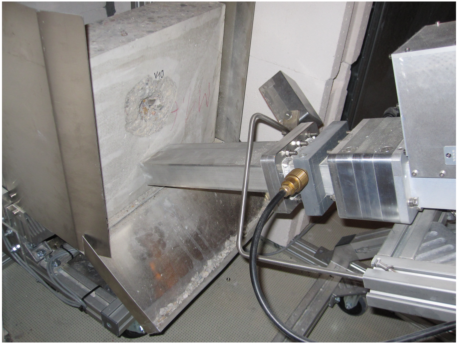


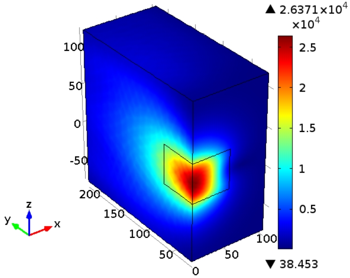
- Microwave ablation of concrete surface (explosive spalling from high thermal stress and pore pressure from water vaporization)
- Material properties
- thermo elastic model with microwave heating
- Results simulation
- Experimental findings
- Conclusion

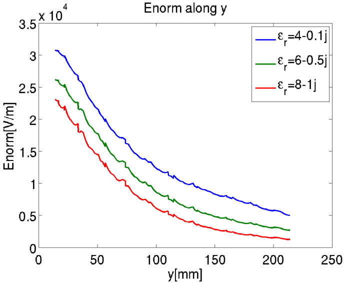
ϵ_r	$\rho\,[kg/m^3]$	$k\,[W/(m.K)]$	$C_p\,[J/(kg.K)]$	ν	$E\,[GPa]$	α
$6-0.5j$	2400	1.7	800	0.12	48	10^{-5}
- in reality the materials properties vary with the water content and temperature
- electromagnetic losses: $P_{em} = \omega\epsilon_0\epsilon^{''} E_{rms}^2$
- Assume isotropic and homogeneous material, electromagnetic part, $\mathbf{D} = \epsilon\mathbf{E}$
- thermal part: Fourrier law, $\mathbf{q}(\mathbf{x}, t) = -k\nabla T(\mathbf{x}, t)$
- mechanical part: linear elastic model, $\boldsymbol{\sigma} = E\boldsymbol{\epsilon}$
- assume constant dielectric, thermal and mechanical properties
- linear thermo elastic model (generalized 3d hooke law) $\boldsymbol{\sigma} = \frac{E}{1+\nu}\boldsymbol{\epsilon} + \frac{E\nu}{(1+\nu)(1-2\nu)}tr(\boldsymbol{\epsilon})\mathbf{I} - \alpha\frac{E}{1-2\nu}(T - T_{ref})\mathbf{I}$

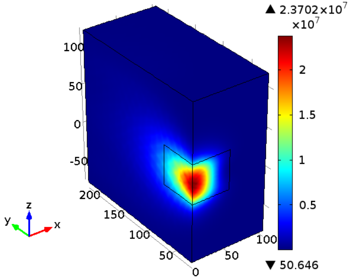
EM, THERMAL AND MECHANICAL MODELS

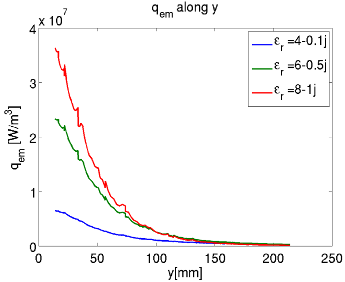
- EM: $\nabla^2\mathbf{E} + \gamma^2\mathbf{E} = 0$; $f = 2.45$ GHz; $P_{in} = \frac{10}{2}$ kW
  BC: boundary conditions, symmetry plane $\nabla \times \mathbf{H} = 0$, waveguide, $\mathbf{n} \times \mathbf{E} = 0$
  concrete surface: radiation boundary condition
- THER: $\rho c_p \frac{\partial T(\mathbf{x},t)}{\partial t} = \nabla \cdot (k\nabla T(\mathbf{x},t)) + q_{em}(\mathbf{x},t)$
  $T_i = 20\,^\circ\mathrm{C}$; solve from 0 to 30 s every 2s
  BC: $\mathbf{n} \cdot \nabla T = 0$
- MEC: $\rho\ddot{\mathbf{u}}(\mathbf{x},t) - \nabla \cdot \mathbf{P}(\mathbf{x},t) - \kappa(\mathbf{x},t) = 0$
  quasi static approximation, inertial therm are neglected (time duration of the "heat pulse " $>>$ time propagation of a elastic wave)
  volume forces (gravity) neglected in comparasion to thermal stress
  BC: symmetry plane: $\boldsymbol{n} \cdot \boldsymbol{u} = 0$, bottom edge, $u_z = 0$; back face $u_y = 0$

Results, E fields, Power density

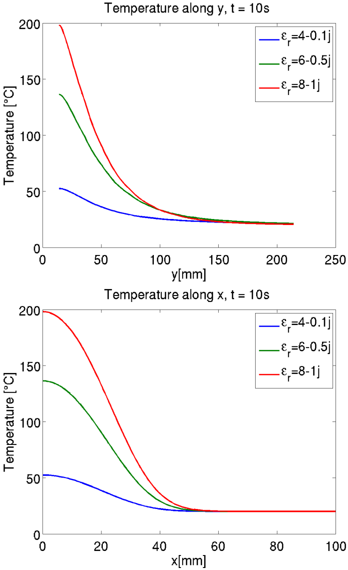


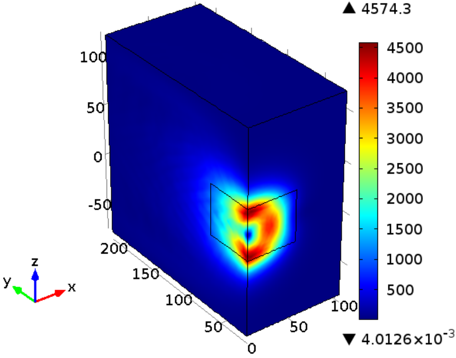




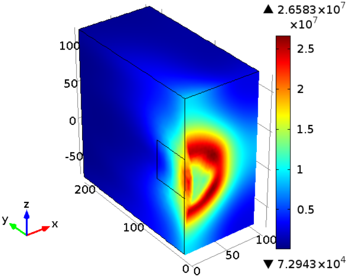


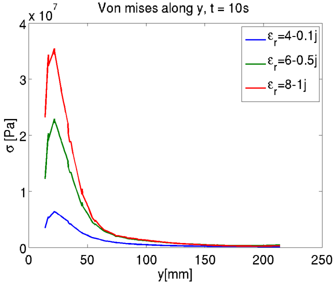
Temperature (°C) and thermal gradient fields

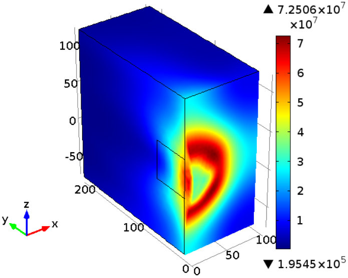


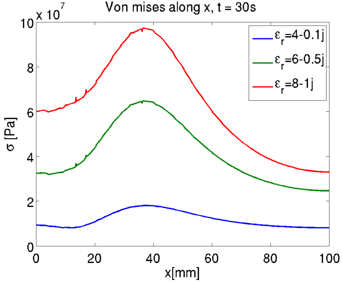


STRESS FIELDS $t = 10, 30$ S

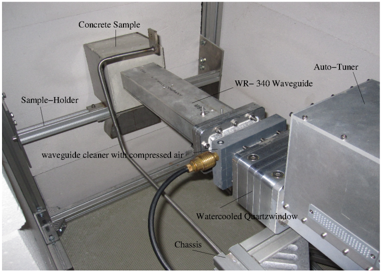


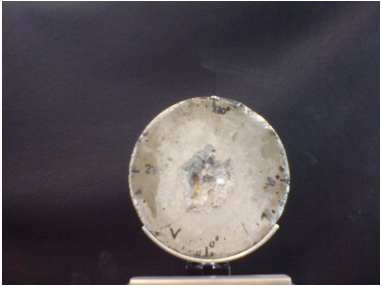


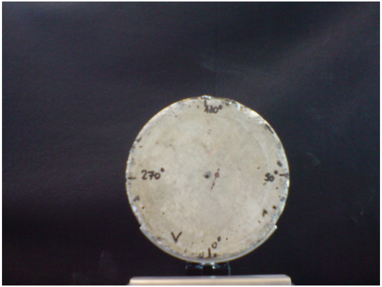


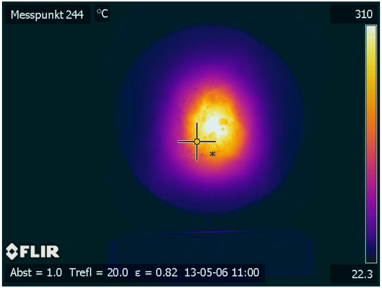


TEMPERATURE MEASUREMENTS









Conclusion and further work

Conclusion

- A thermo elastic model of microwave heating of concrete is useful for the design of an applicator
- It allows to calculate the electric field, power density, displacements and stress fields
- pore pressure and water movements are not taken into account with the current model
- Experimental tests shows that ablation size is function of the input power, water content, porosity and sample size

Further work

- antenna matching
- higher frequency
- mechanics: optimal stress pattern?
- modelling: porous model with water and vapour transport
- temperature and displacements measurements

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Thank you for your attention