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Numerical Treatment of Coupled Electro- Thermo- Mechanical Effects in Contact Problems

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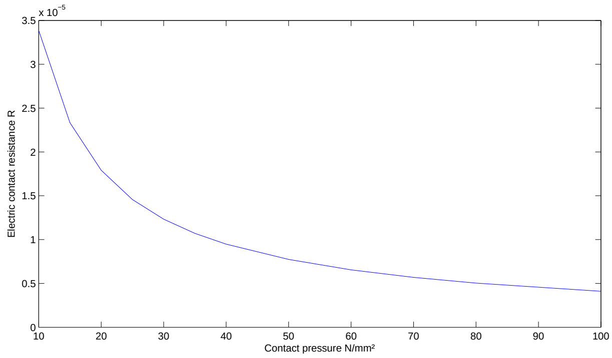
ABSTRACT

In this study, a nonlinear finite element algorithm for electro-thermo-mechanical contact problems is developed and implemented in a finite element code. First, the principles of electromagnetism, in particular the Maxwell equations, are added to the well-known principles of continuum mechanics [1], to get all the considered fields fully coupled. To make the formulation also accessible for semiconductors thermoelectric phenomena like Seebeck, Thomson and Peltier effects are included in the constitutive equations for the field and the contact interface.

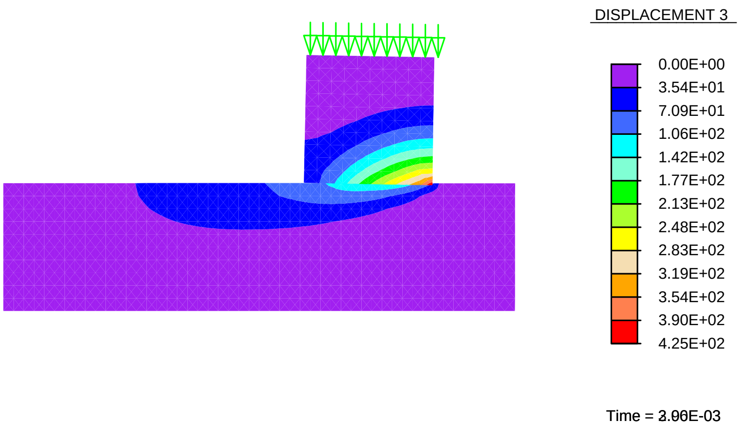
Due to micromechanically rough surfaces in the contact zone only a small portion of the whole surface is electrically conductive. Therefore a constriction resistance exists [2], which causes additional heat generation in the contact interface. Like the computations for thermomechanical contact analysis [3], a pressure dependent formulation for the current flow and the joule heating in the contact zone is developed.

In the case of frictional contact the influence of current on wear has to be considered [4]. Archard's law of wear is supplemented by an additional term regarding the current and implemented in Coulomb's law of friction. This leads to an additional evolution equation for the magnitude of the surface roughness. This magnitude changes the penetration and therefore not only the pressure, as noted above, but also the current flow and the joule heating.

Nonlinearities arise due to the coupling of electrical, thermal and mechanical fields, the dependence of the material parameters on temperature and the contact constraints. These nonlinearities are treated by a consistent linearization within a Newton-Raphson algorithm. For coupled problems it is assumed that staggered solution schemes are more efficient than monolithic ones. Both solution techniques were implemented and will be compared regarding the efficiency.



Pressure dependency of the electrical contact resistance in the contact interface.



Temperature distribution based on frictional dissipation and joule heating. (pressure: 10 $\frac{N}{mm^2}$)

Numerical simulations are compared with experimental results from [1,4], in particular the pressure dependency of the resistance, voltage drop, specific wear rate and electrical and frictional power loss are used to validate the electromechanical contact formulations. Additional examples demonstrate some special effects like the pressure dependency of joule heating in the contact interface.

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