Operation of an Electromagnetic Trigger with a Short-circuit Ring

Dejan Križaj¹, Zumret Topčagić¹, and Borut Drnovšek¹,²

¹ Faculty of Electrical Engineering, University of Ljubljana, Ljubljana, Slovenia,
²RC NELA, Izlake, Slovenia

Excerpt from the Proceedings of the 2012 COMSOL Conference in Milan
Outline

- Electromagnetic trigger
  - Usage
  - Selective circuit breaker
  - Problem of a movable contact
- Model
- Results
- Conclusions
Miniature circuit breaker - MCB
Electromagnetic trigger

\[ \sigma \frac{\partial A}{\partial t} + \nabla \times H = J_e \]

\[ E = -\nabla V - \frac{\partial A}{\partial t} \]
Results – without a ring
Absolute value of magnetic flux density at the current of a) 72A and b) 200 A.

Linearized B(H) curve

Tabulated B(H) curve
Results – ring included

Absolute value of magnetic flux density $I_{RMS}=283\,A$ after a) 35 ms and after b) 40 ms.
Force calculation

\[ F = \oint_{\partial \Omega} \mathbf{n}_1 T_2 dS \]

\[ \mathbf{n}_1 T_2 = -\rho \mathbf{n}_1 - \left( \frac{1}{2} \mathbf{E} \cdot \mathbf{D} + \frac{1}{2} \mathbf{H} \cdot \mathbf{B} \right) \mathbf{n}_1 + (\mathbf{n}_1 \cdot \mathbf{E}) \mathbf{D}^T + (\mathbf{n}_1 \cdot \mathbf{H}) \mathbf{B}^T \]

\[ \tau = \frac{1}{\mu_0} \begin{vmatrix} B_x^2 - \frac{1}{2} B^2 & B_x B_y & B_x B_z \\ B_y B_x & B_y^2 - \frac{1}{2} B^2 & B_y B_z \\ B_z B_x & B_z B_y & B_z^2 - \frac{1}{2} B^2 \end{vmatrix} \]

\[ f = \frac{B_n^2}{2 \mu_0} \approx \frac{\Phi^2}{2 \mu_0 A^2} \]
Comsol adjustments

- **Mesh:** Typical number of mesh points was 28150.

- **Study:** A *Time Dependent simulation* (study) and *Magnetic Fields* (mf) physics
  - two *Ampere’s Law* sections (one for linear materials and one for nonlinear parts (anchor, yoke and core))
  - *Gauge Fixing for A-Field* was selected

- **Solver:** *Absolute tolerance* in the *Time Dependent Solver 1* settings for the first variable was set to Unscaled /1e-5 and for the second to Unscaled/8e-3. *Maximum BDF order* in *Time stepping method* solver was set to 2. Direct solver (in our case MUMPS) was used. In the *Fully Coupled 1* settings in the *Time Dependent Solver 1* section for Linear solver was selected *Direct* option, for Jacobian update was selected *On every iteration* option and *Maximum number of iteration* was set to 25.
Conclusions

✓ Operation of an electromagnetic trigger with a short circuit ring has been successfully studied by numerical simulation.

✓ Operation of the device at high currents resulting in magnetic field saturation effects requires some tuning of Solver parameters.

✓ Nonzero anchor force at zero current in coils is a result of induced current in the ring adding a tangential component to the force.

✓ Comsol Multiphysics is becoming one of the key players in the ever more important field of multiphysics modeling.
Results – just a video

Tule video z ringom