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Design and Simulation of an Electromagnetic Valve Actuator Using COMSOL Multiphysics

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Overview

- Motivation
- Electromagnetic Valve Actuator (EMVA)
- Simulation
- Summary

Motivation

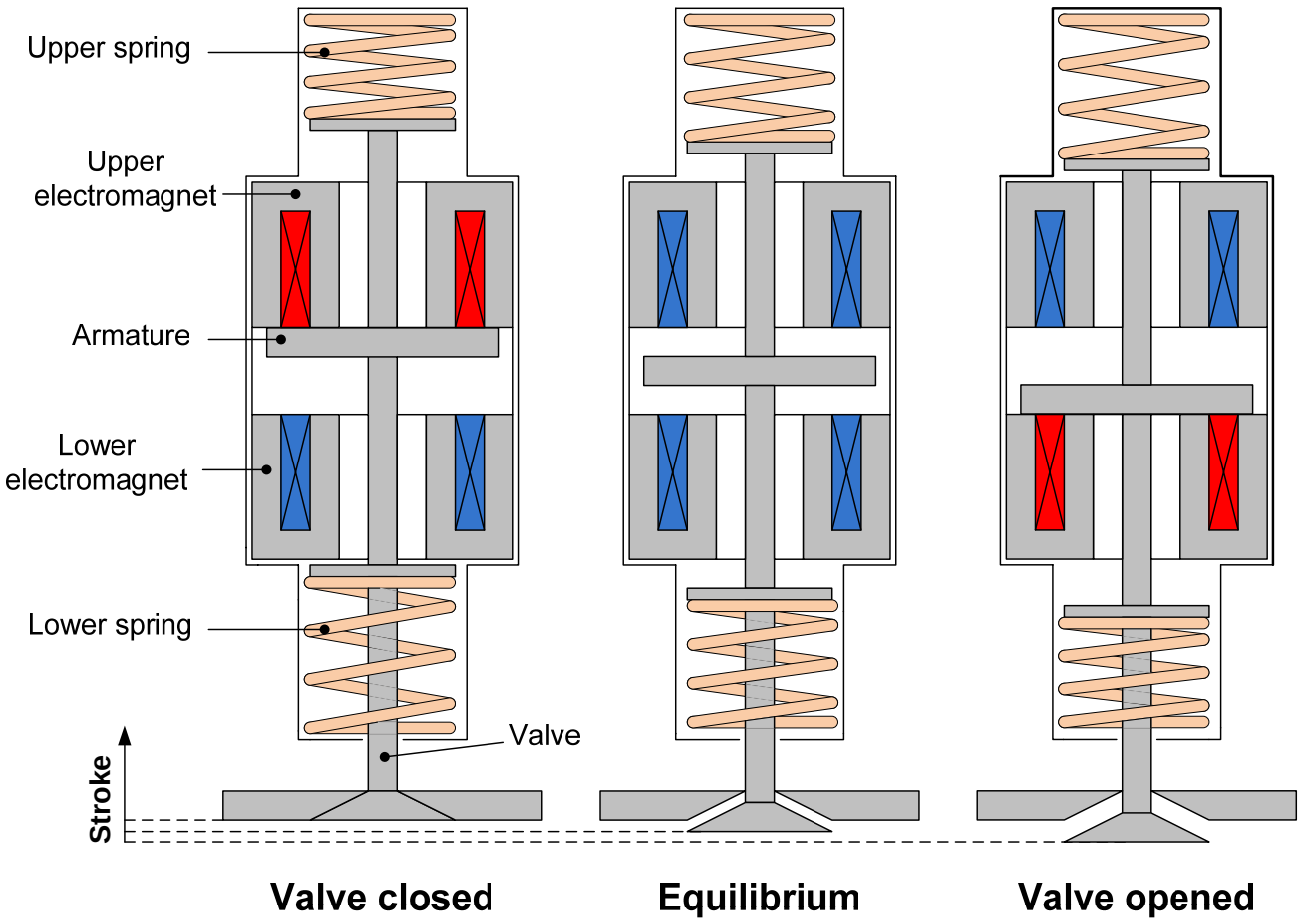
- Scope:
  - Limited resources of crude oil and stringent emissions regulations are forcing the automotive industry to develop more efficient gasoline engines

    ➡ Variable engine valve actuation systems

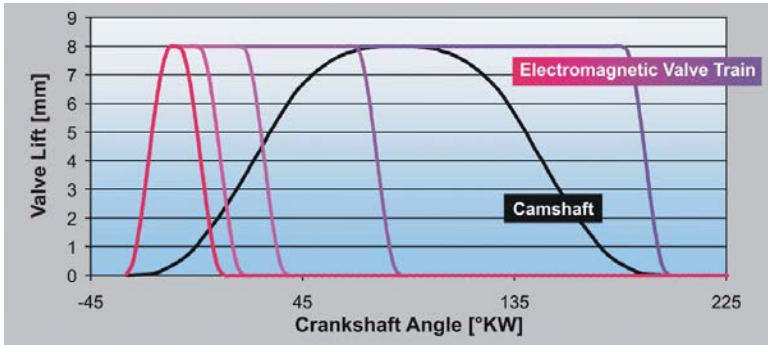
    ➡ Electromagnetic Valve Actuator (EMVA)

- Aim:
  - Design and analyze the EMVA by the finite element method (FEM) using COMSOL Multiphysics

Electromagnetic Valve Actuator



Opening and the closing events can be shifted with respect to the crankshaft angle

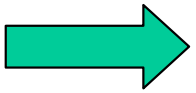


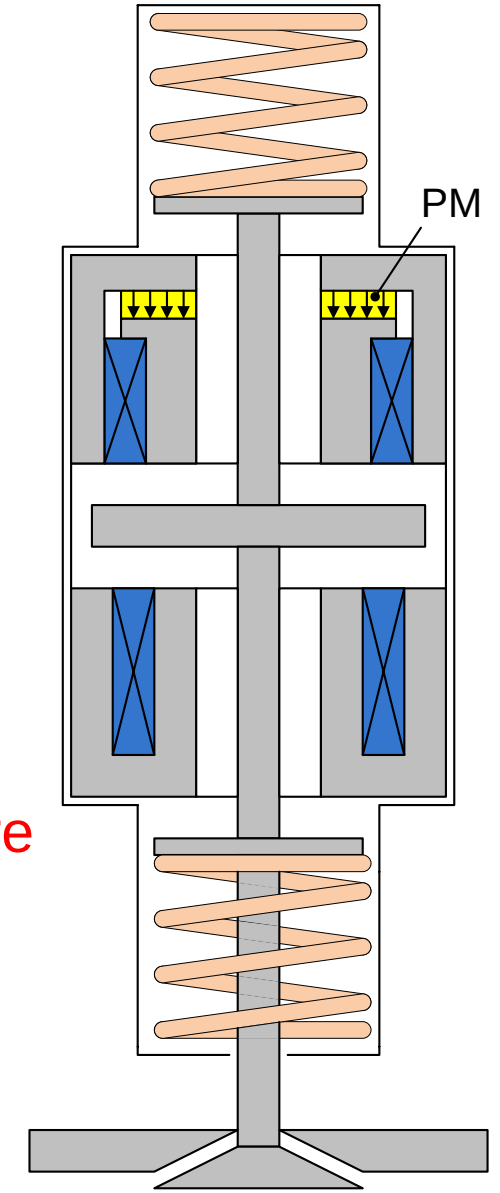
- Optimization of the combustion process depending on the engine load and speed
- The aspirated air mass during the intake stroke can be regulated without a throttle valve

Electromagnetic Valve Actuator

- In the opened and closed positions electrical power is needed to enable the electromagnets to hold the armature against the spring stiffness

- During operation the duration of the closed state is much greater than the one of the opened state





Drawbacks of the EMVA with PM:

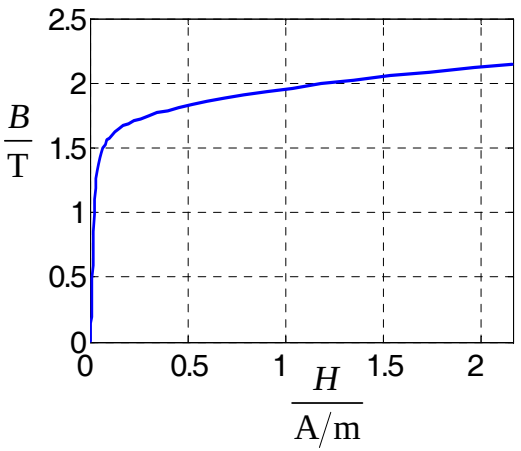
- ➢ Electrical power is needed to release the armature
- ➢ Less space for the coil is available

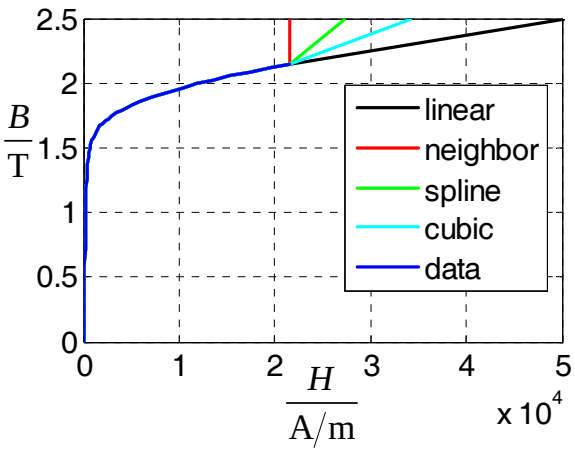
- Nonlinear B-H curve:

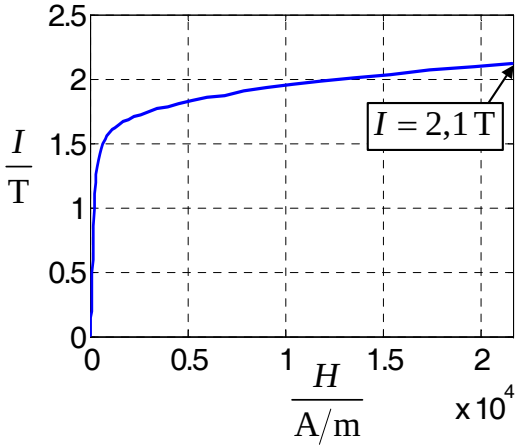
$$B = \mu_0 H + I \quad \text{with} \quad I = \mu_0 M$$

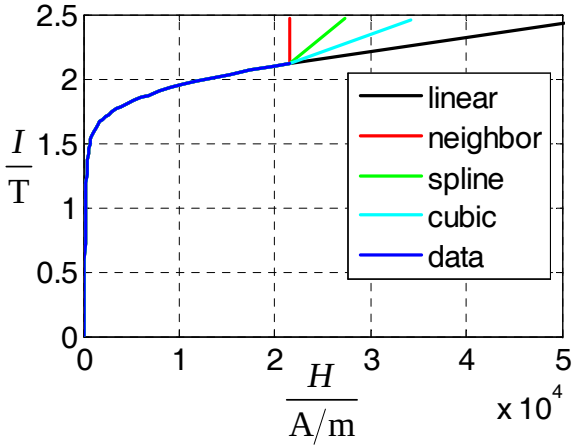
Cobalt-Iron alloy with $I_S = 2{,}2\ \mathrm{T}$

Available data are incomplete !



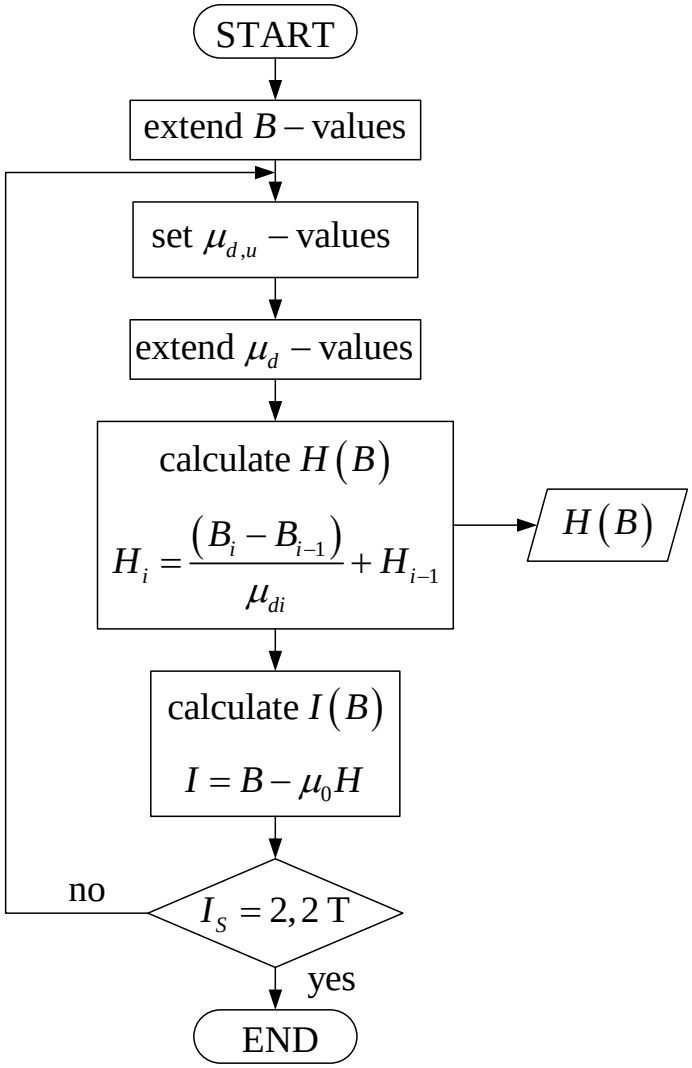




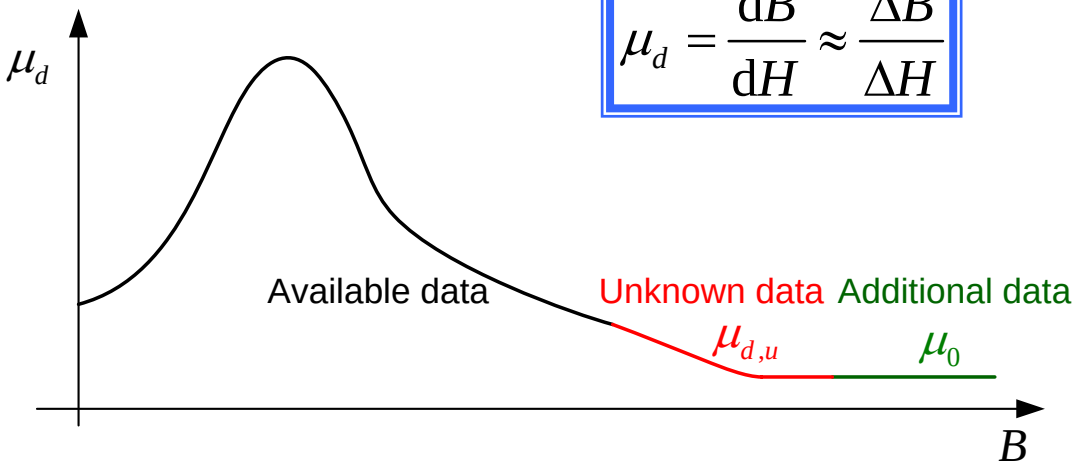


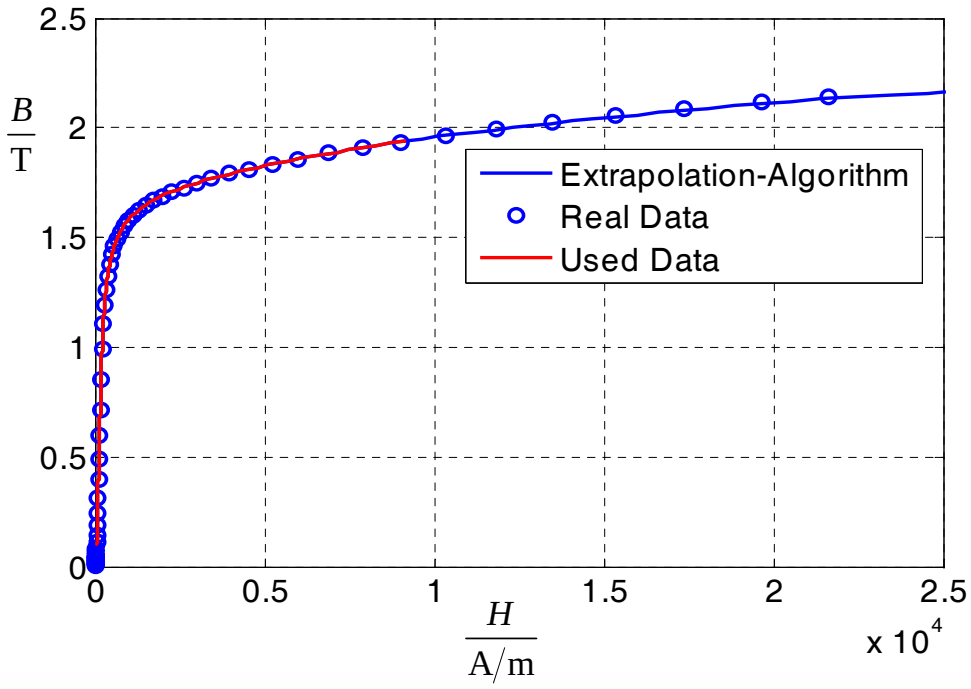
- Extrapolation methods in COMSOL:
  - Linear
  - Nearest Neighbor
  - Cubic Spline
  - Piecewise Cubic

- Extrapolation Algorithm:



$$\mu_d = \frac{\mathrm{d}B}{\mathrm{d}H} \approx \frac{\Delta B}{\Delta H}$$

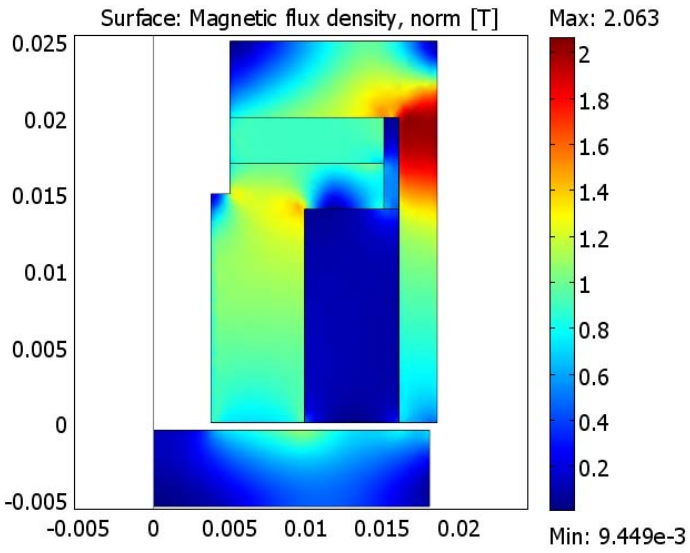


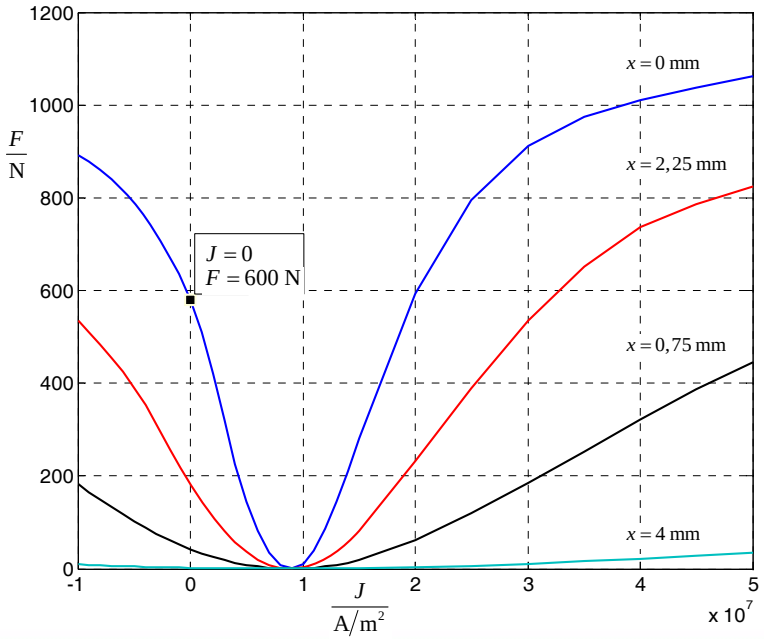


- Axially symmetrical 2D FEM model in COMSOL Multiphysics is used

- Initial value for vector potential: $\alpha\sqrt{\left(r^2+z^2\right)}$

```
alpha=1e-3;
try
    comsol_simulation(alpha);
    error(lastwarn);
catch
    while(lastwarn)
        lastwarn('');
        alpha=(rand(1,1));
        comsol_simulation(alpha);
    end
end
```





Conclusion

- A new electromagnetic valve actuator with permanent magnet has been presented
- The analysis has been made using the finite element method in COMSOL Multiphysics
- A new algorithm to extend B-H-curves has been developed