Optimizing Performance of Equipment for Thermostimulation of Muscle Tissue using COMSOL Multiphysics

Jan Kocbach¹, Kjetil Folgerø¹, Louise Mohn², Ole Brix³

1. Christian Michelsen Research AS, P.O. Box 6031, NO-5892 Bergen, Norway.
2. Luzmon Norway AS, Norway.
3. Michelsen Medical AS, P.O. Box 6027, NO-5892 Bergen, Norway

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**Introduction**

Thermostimulation = Heating therapy + Electric stimulation of muscles

- **Optimal stimulation:** Electric field in muscles must be above stimulation threshold
- **Painless treatment:** Electric field in nerve region must be below pain threshold
- **Thermostimulation:** High temperature required in muscles for hyperthermia
- **Avoid overheating:** Upper temperature limit of 42 °C at skin surface / inside body

**Project target:** Build simulation models which can be used to make optimal design choices for thermostimulation equipment: electrode layout and electrode material, heat pad layout, alternative heating methods, effect of body composition on stimulation effect, etc.

**Use of COMSOL Multiphysics**

**Model setup:** Heating and heat transfer simulations

- Body tissue modelled as layered structure - bone, muscle, fat, skin
- Heat pads modelled as additional outer layers of silicone rubber and heat wire layer
- AC/DC module used for heat wires. Heat Transfer module with Penne’s Bio-heat equation for heat transfer into body

**Use of COMSOL Multiphysics**

**Model setup:** Electrical stimulation simulations

- Body tissue modelled as layered structure
- Electrodes and heat pads modelled as separate thin layers on top of skin layer
- **Model variants:**
  - Finite thickness electrodes with varying electrical conductivity
  - Thin high conductivity electrode wires below electrodes
  - Conductive gel layer with ‘gel leakage’ between electrodes
  - Non-conductive air-layer between electrodes
- **Simulation results evaluation:**
  - Electric field / electric current evaluated along lines at muscle/fat layer boundary
  - Area in muscle cross section with electric field above certain threshold value identified
  - 3D contour plots to visually investigate difference in electric field

**Figure 3:** Heating and heat transfer model

**Figure 4:** Electrical stimulation model

**Reference:**


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**Results**

1. **Heating for different body compositions**

  - Fat layer thickness influences significantly on both pre-heating time and final temperature
  - Need to plan long pre-heating for patients with thick fat layers

2. **Effect of heat wire separation**

  - Heat wire separation critical design parameter – large spacing gives uneven heat
  - 5 mm heat wire spacing leading to significant lowering of heat in the muscle tissue

3. **Effect of electrode conductivity**

  - Low electrode conductivity better from production point of view – gives uneven stimulation
  - Either conductivity σ > 40 S/m required for even stimulation
  - Alternative: Use conductive wire electrode (not shown, see Kocbach et al 2011)

4. **Focusing of electric field due to gel leakage**

  - Leakage of gel to gap between electrodes leads to strong focusing effects
  - 100% gel with case gives significantly reduced electric field in muscle (Kocbach et al 2011)

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