Simulation of Oil Sands Induction Heating using Voltage-Driven Coils with Magnetic Core

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INTRODUCTION: Due to several limitations of steam injection in oil sands recovery, alternative solutions such as solvent injection and electromagnetic heating methods are explored. Induction heating of oil sands is based on inducing eddy currents in the reservoir by means of electromagnetic induction. The current is dissipated in the subsurface connate water and thus the water is converted to steam. Induction heating of oil sands can be considered as an in-situ steam generation method. The aim of this simulation work is to investigate the feasibility of using a voltage-driven coil incorporating a magnetic core to raise the temperature of oil sands to sufficient levels that allow oil recovery.

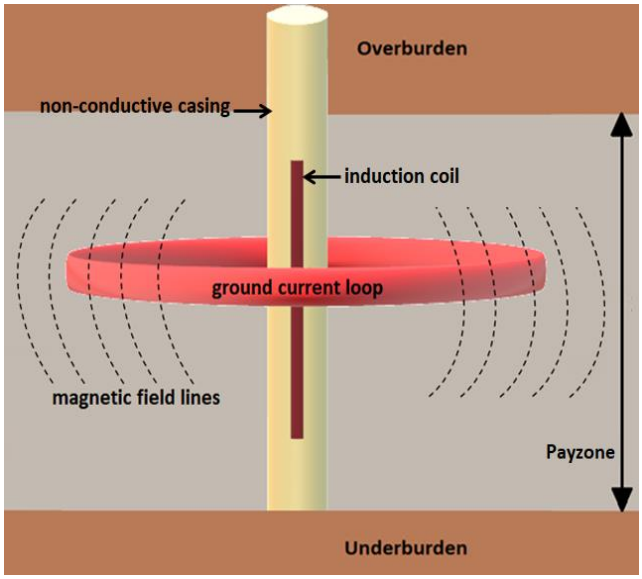

Figure 1. Application of induction heating in oil sands

COMPUTATIONAL METHODS:

$$\rho C_p \frac{\partial T}{\partial t} + \rho C_p \mathbf{u} \cdot \nabla T = \nabla \cdot (k \nabla T) + Q_{rh} + Q_{ml}$$

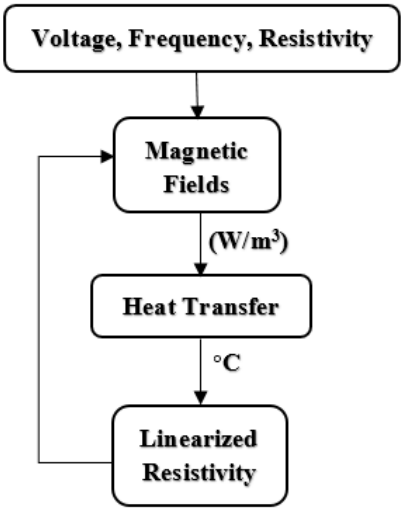

Figure 2. Simulation Workflow in COMSOL.

RESULTS: The temperature increases rapidly in the first few days of heating, then heat penetration slows down towards the end of the simulation.

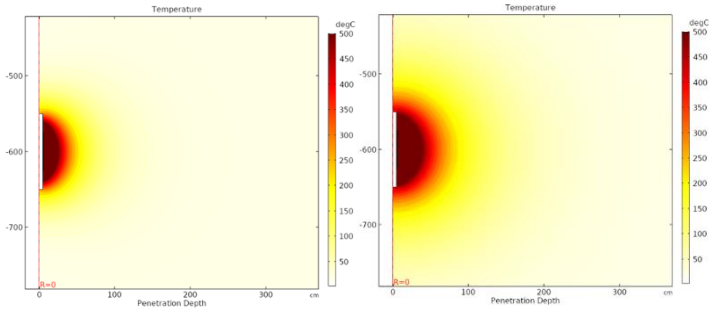

Figure 3. Temp. after 5 days

Figure 4. Temp. after 35 days

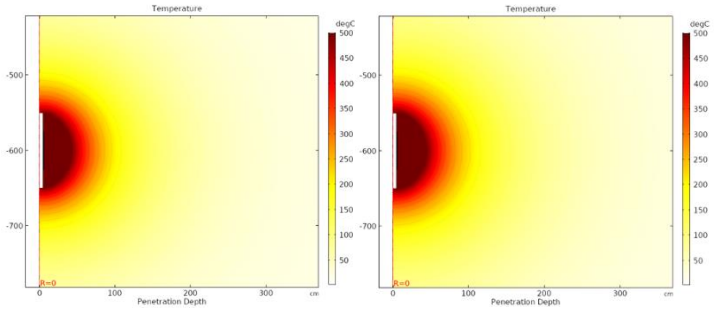

Figure 5. Temp. after 70 days

Figure 6. Temp. after 100 days

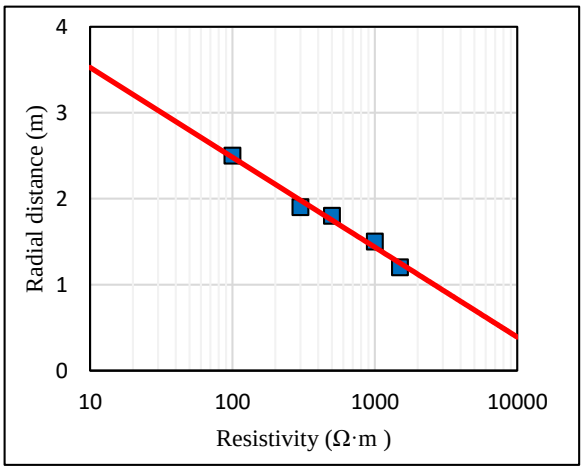

Figure 7. Radial distance heated to $100°C$ vs. oil sands resistivity.

CONCLUSIONS:

- The operating frequency only impacts the input power and not the heat distribution.
- Induction heating of oil sands is feasible and more effective in formations with lower resistivity.
- Building on this study, we have started the process of coupling the Magnetic Fields interface to a reservoir simulator.

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