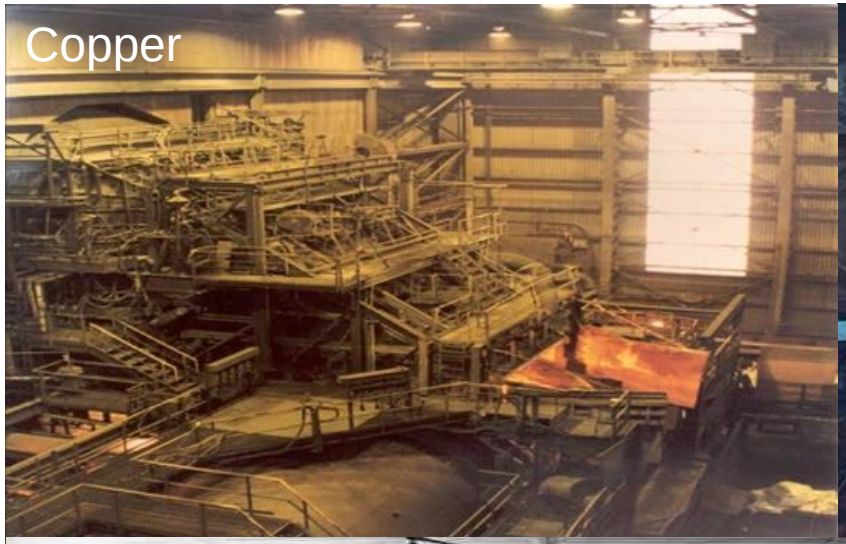
Inverse Identification of the Time-Varying Shape of a Phase Change Bank in a High Temperature Melting Furnace

Marc-André Marois
Martin Désilets and Marcel Lacroix, director
Université de Sherbrooke


Copper

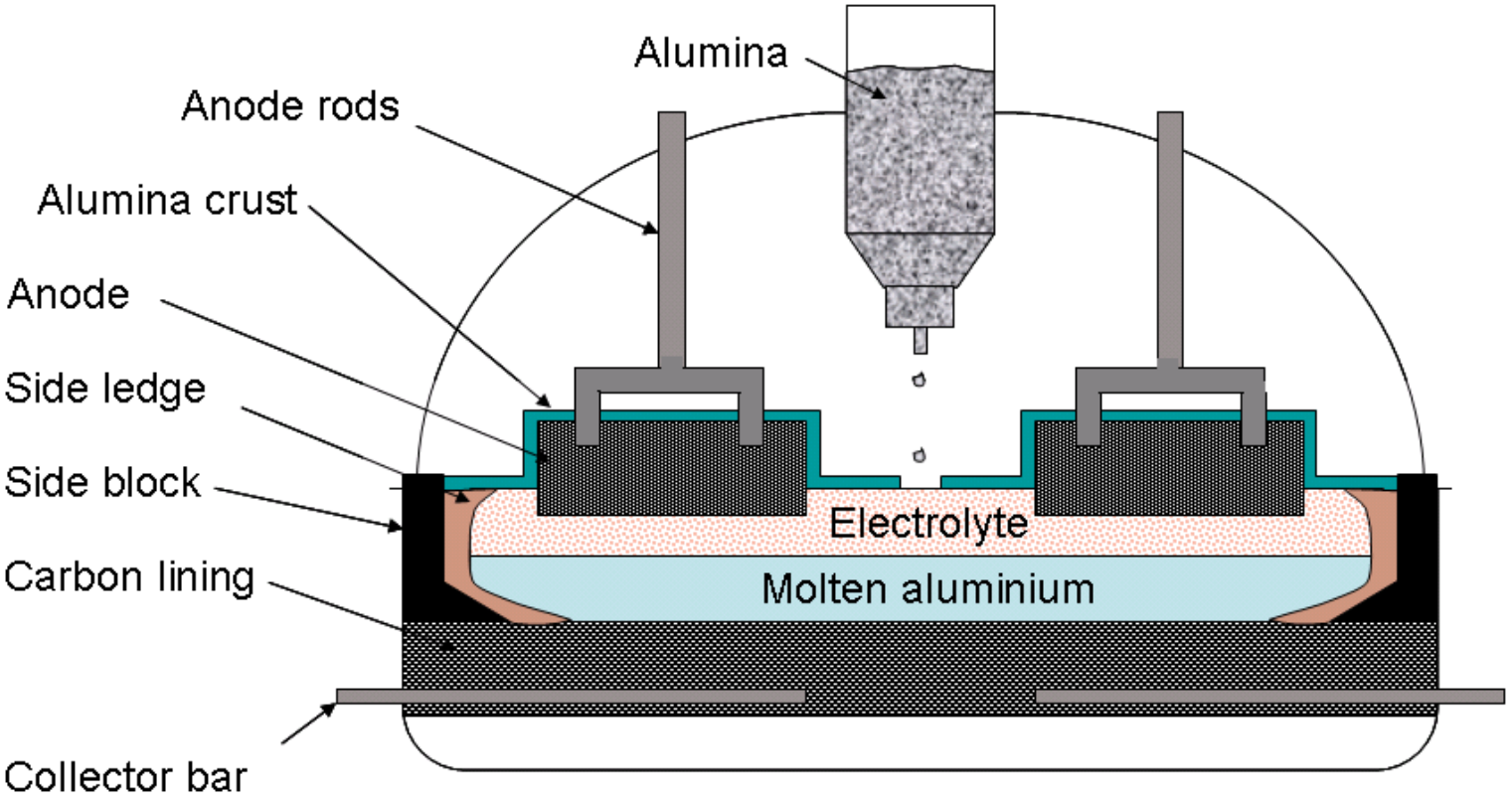

Iron


Aluminium

Thermal system description

Presentation outline

- **Introduction**
- Direct problem
- Inverse problem
- Results
- Conclusion

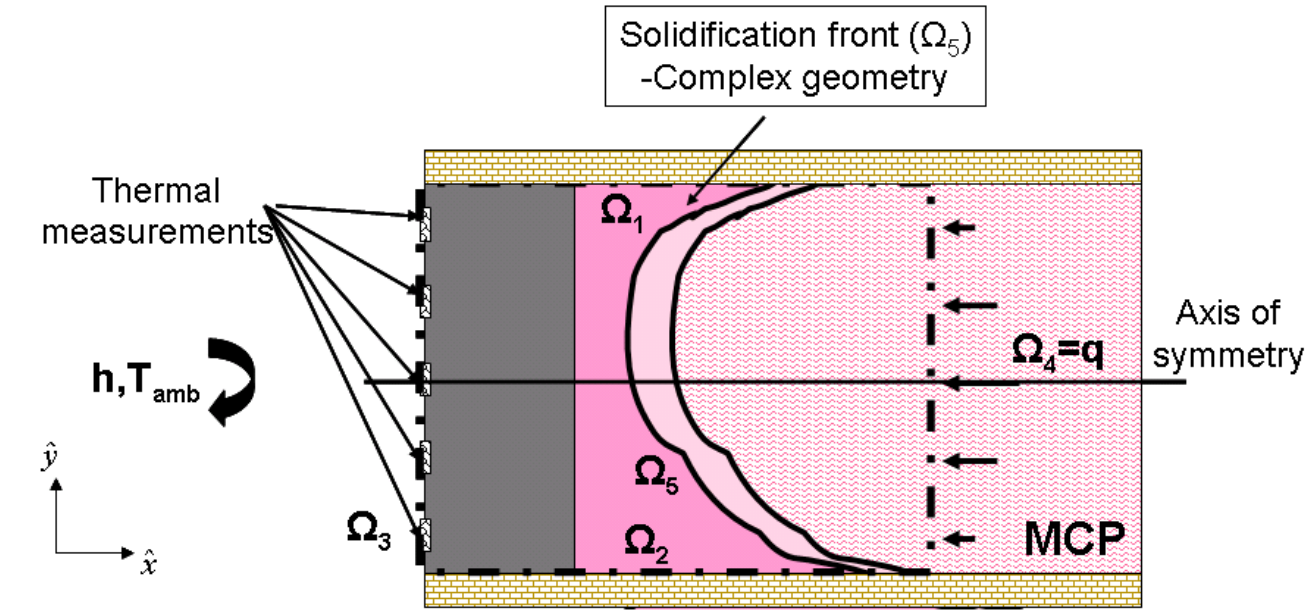


Objective: *Develop an alternative fast and simple inverse heat transfer procedure*

Direct heat transfer problem

Presentation outline

- Introduction
- **Direct problem**
- Inverse problem
- Results
- Conclusion



Boundary conditions (control volume):

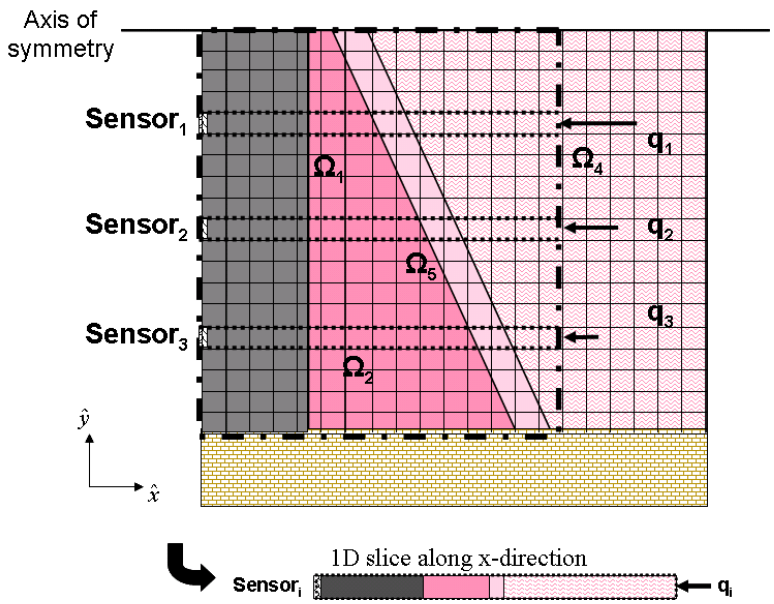
- $\Omega_1 = \Omega_2$: Adiabatic
- Ω_3 : Convection cooling
  Thermal measurements
- Ω_4 : Unknown heat flux (linear gradient)
- Ω_5 : $T = T_S$; Unknown estimated geometry

Direct computational

Presentation outline

- Introduction
- **Direct problem**
- Inverse problem
- Results
- Conclusion

- Transient, cartesian and 2D
- Source-based enthalpy method
- Finite volume method
- Validated with Swaminathan and Voller works (1991)



Inverse heat transfer problem

Presentation outline

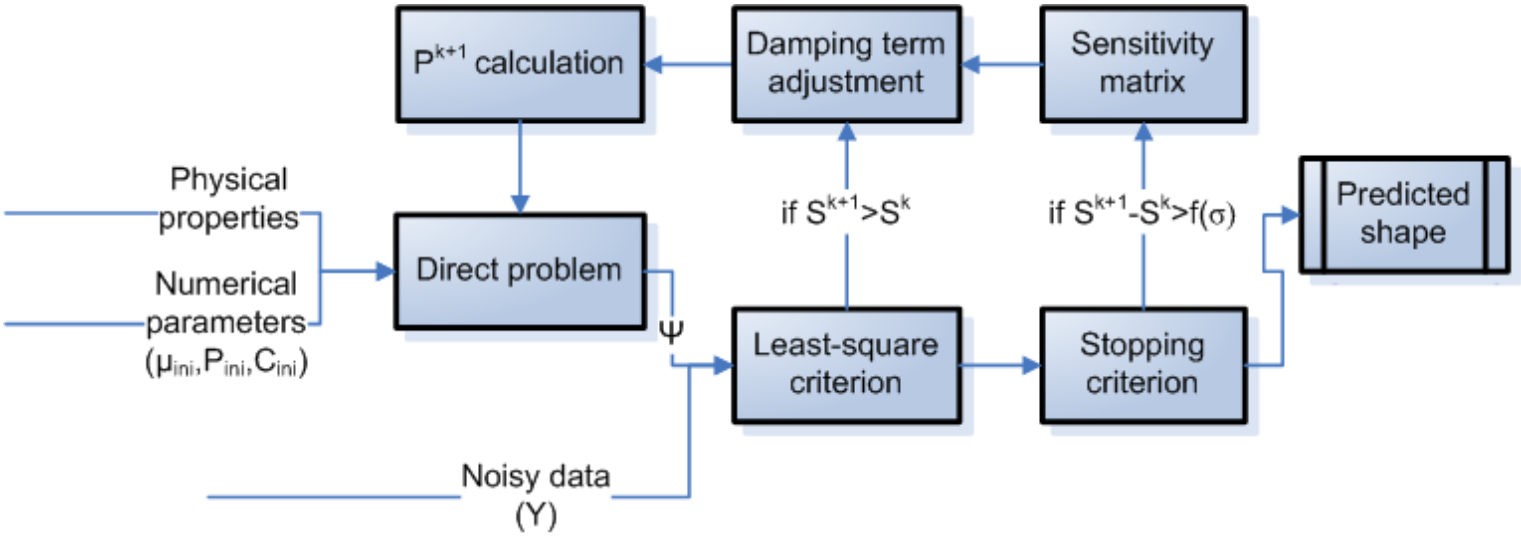
- Introduction
- Direct problem
- **Inverse problem**
- Results
- Conclusion

- Classification : unknown boundary geometry
- Tracking problem vs control problem
- Input/output parameter:
  - Temperature / time-varying shape of the bank
  - Temperature / Heat flux on the Ω_4 boundary
- Criterion to be minimised: least square function
- Levenberg-Marquardt method for parameter estimation
- Whole time domain analysis

The inverse heat transfer procedure

Presentation outline

- Introduction
- Direct problem
- **Inverse problem**
- Results
- Conclusion



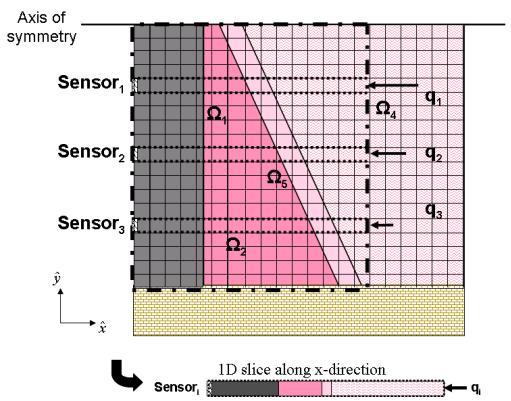
- Linear interpolation of q on the Ω_4 boundary
- Finite difference approximation for sensitivity coefficients

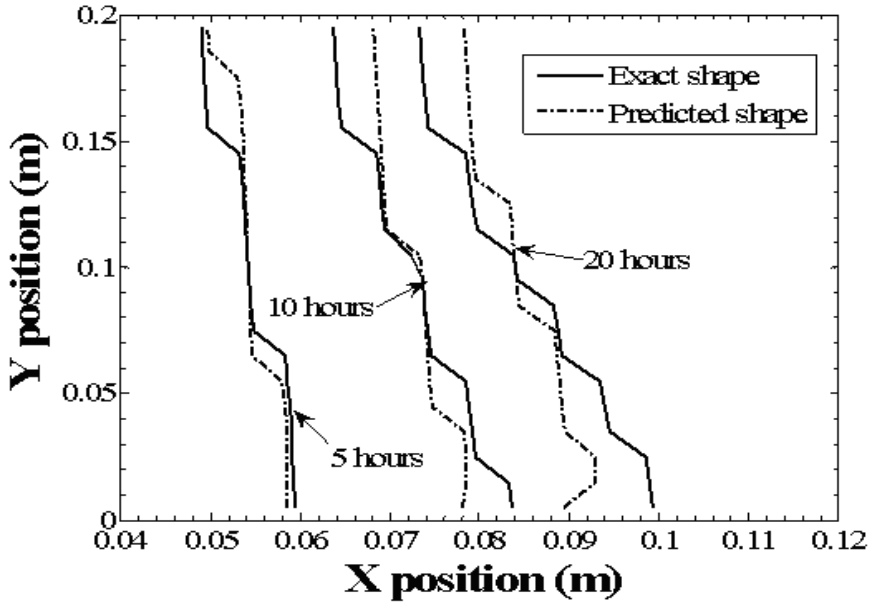
Typical phase change problem

Presentation outline

- Introduction
- Direct problem
- Inverse problem
- **Results**
- Conclusion

- Physical properties of a typical high temperature furnace
- Sampling period (T) : steady-state is reached
- 3 sensors with σ=1%





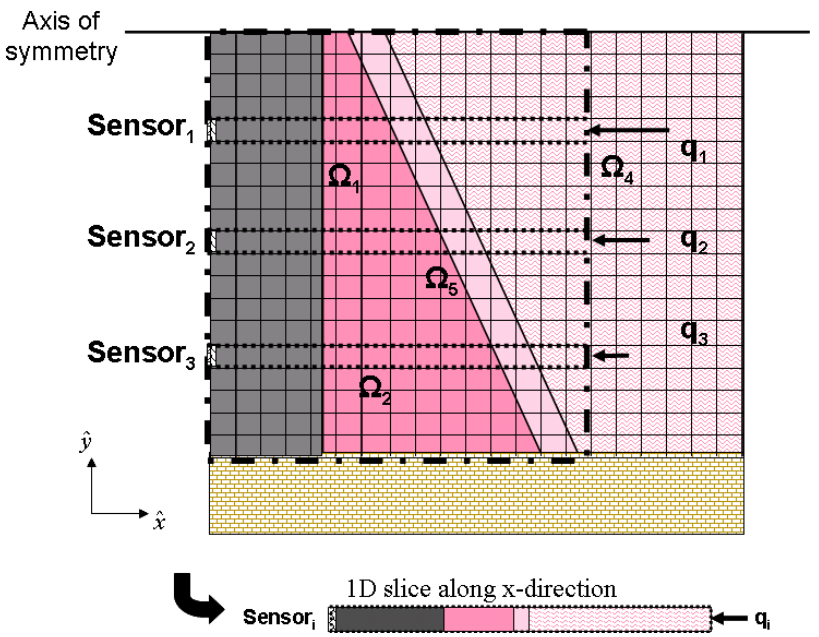
Typical phase change problem

Presentation outline

- Introduction
- Direct problem
- Inverse problem
- **Results**
- Conclusion

- Effect of key parameters
  - Prediction accuracy as precise as *dx*
  - σ vs T
  - Sensors' location
  - Number of sensors

Need a less computational intensive inverse procedure!!!

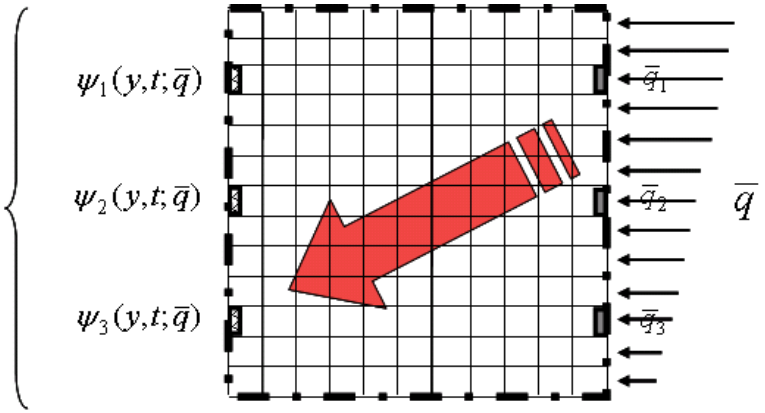


Alternative quasi-2D model

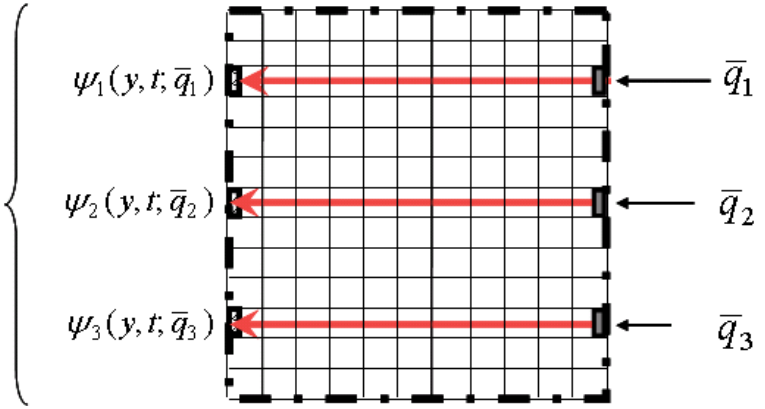
Presentation outline

- Introduction
- Direct problem
- Inverse problem
- **Results**
- Conclusion

2D model



Quasi-2D model

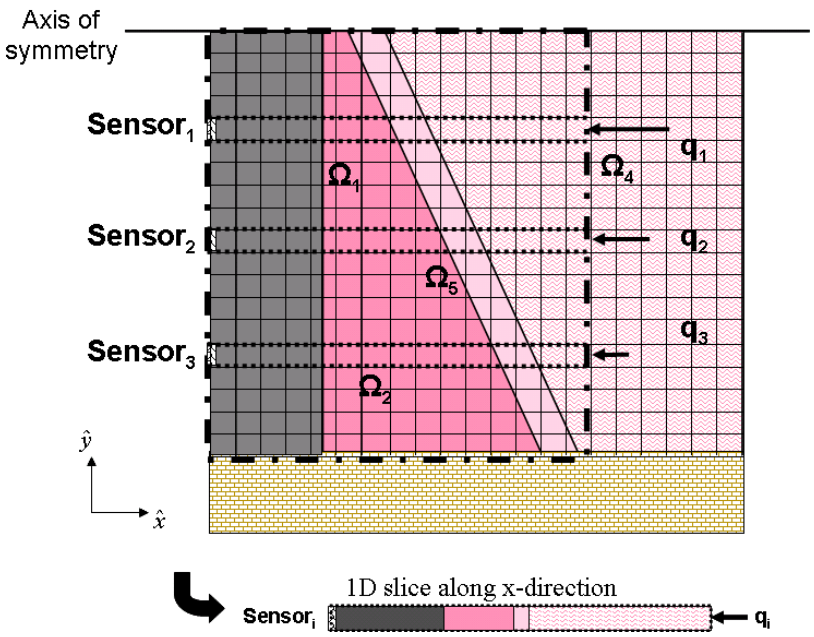


Alternative quasi-2D model

Presentation outline

- Introduction
- Direct problem
- Inverse problem
- **Results**
- Conclusion

- Negligible 2D effects
  - Small aspect ratio
  - Large liquid-to-solid *k* ratio
  - Small *Bi*

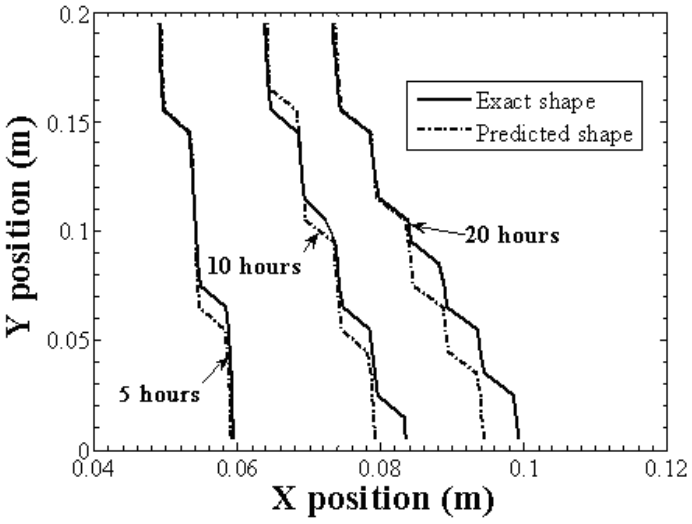


Alternative quasi-2D model

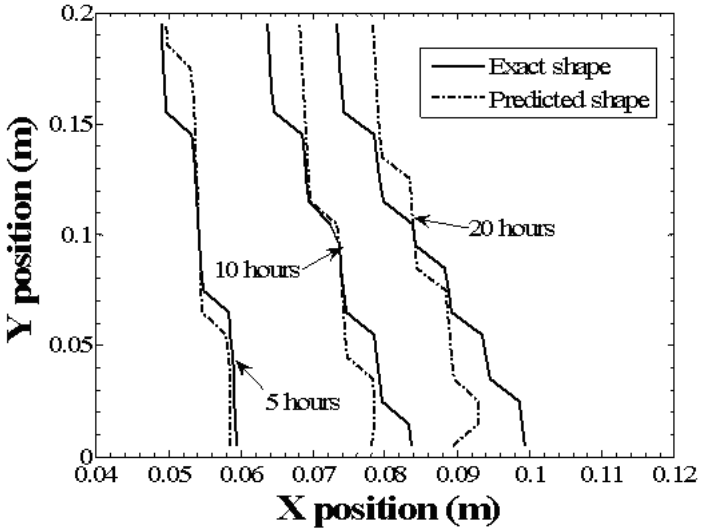
Presentation outline

- Introduction
- Direct problem
- Inverse problem
- **Results**
- Conclusion

Quasi-2D model



Previous 2D model



5 hours **46 hours**

CPU requirement

Conclusions

- The inverse procedure presented
  - Gives accurate predictions for the typical thermal system studied.
- The alternative quasi-2D vs 2D model
  - About 90% less time consuming for the typical thermal system studied.

Presentation outline

- Introduction
- Direct problem
- Inverse problem
- Results
- **Conclusion**

Acknowledgements

Michel Barrette, CCS support

Natural Sciences and Engineering Research Council of Canada (NSERC)

Réseau québécois de calcul de haute performance (RQCHP)

Rio Tinto Alcan fund

Questions???