Heat Transfer &. Solidification Model CON1D

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Improvements to CON1D5.0

- CON1D version 5.0 manual and new format of input file
- New output file XXXX.frc, which out put the phase fractions of shell surface and a certain depth (user input) under surface
- New spray zone model
- New oscillation mark model
- New taper calculation model
- Cooling water temperature rise adjustment by the program itself

$$\Delta T_{\text{modified cooling water}} = \Delta T_{\text{cooling water}} * \frac{w_{ch} d_{ch}}{L_{ch}} * \frac{slab\ width}{totcharea}$$

- make model calibration with water ΔT measurement easier

New spray zone model

- different spray conditions can be chosen

$$h_{spray} = AQ_w^{\,n}(1 - bT_0)$$

where Q_W is spray flow rate, unit l/m^2s

Nozaki Model: A=0.3925, n=0.55, b=0.0075

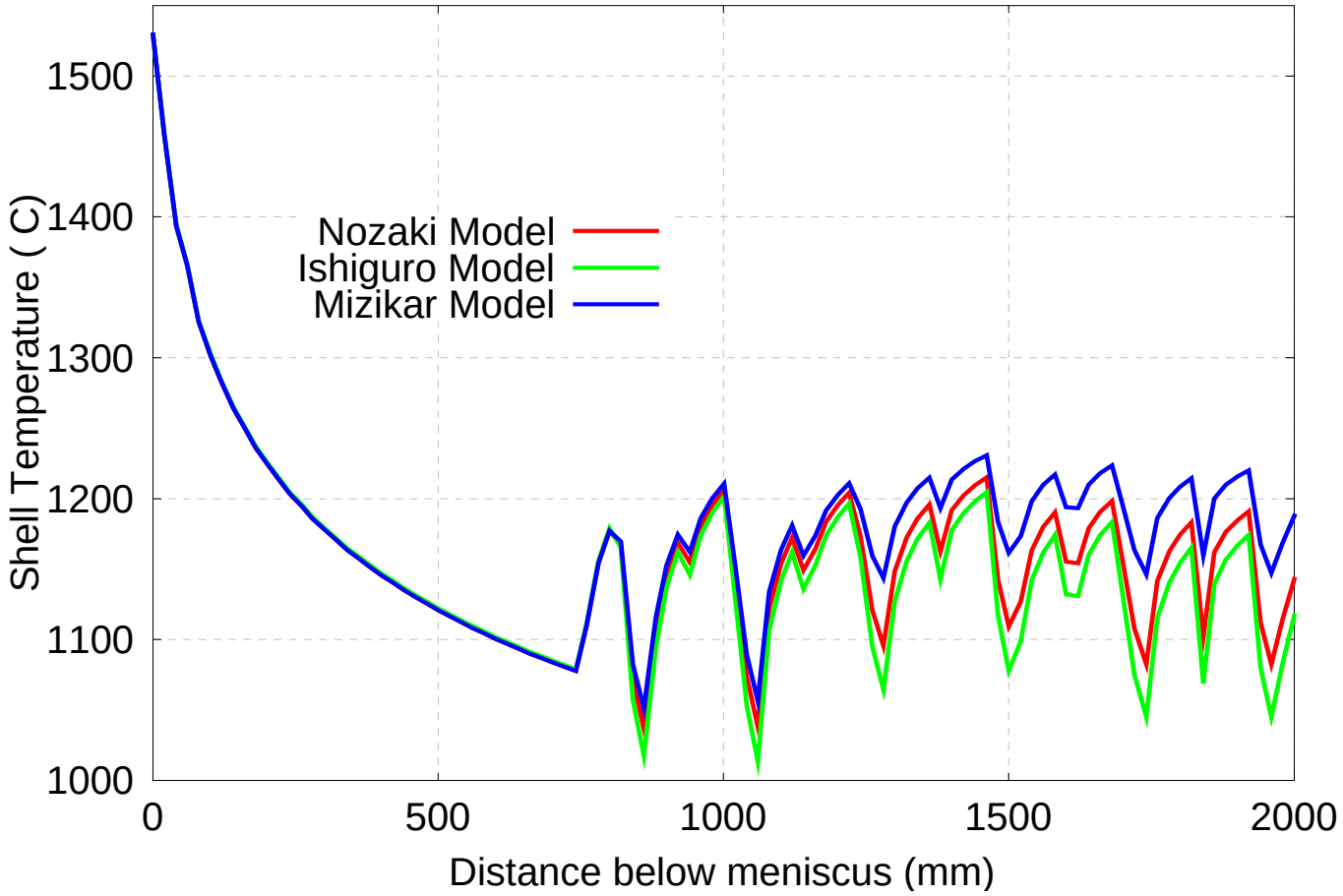
Ishiguro Model: A=0.581, n=0.451, b=0.0075

Mizikar Model (at 276kPa): A=0.0776, n=1, b=0

- more user control spray zone parameters for parametric study

  - e.g. spray zone length and width, roll contact angle etc.

Spray Zone Models Comparison



New oscillation mark model

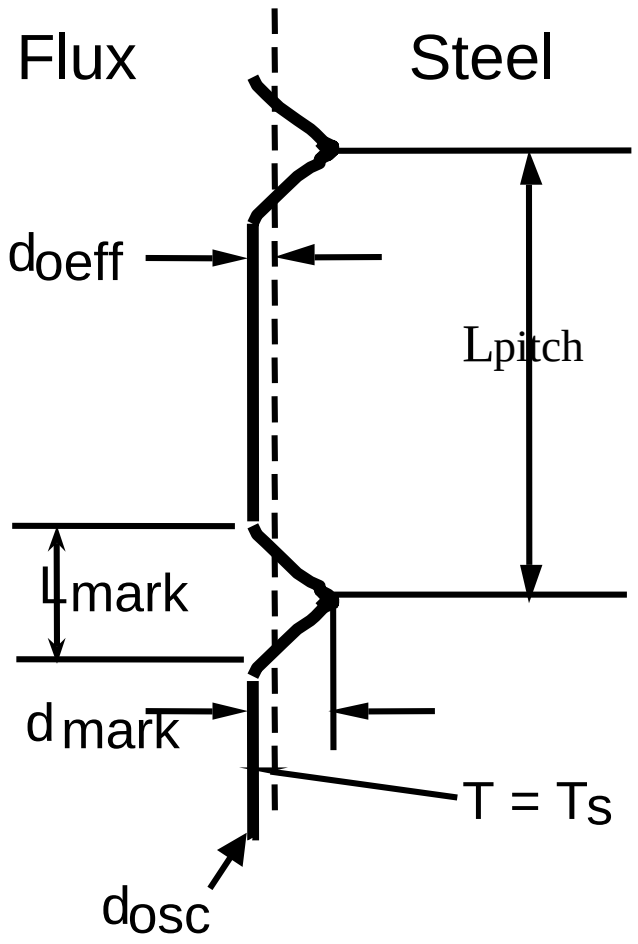
- ioscflag=0 (average osc.thickness)

$$d_{avg} = d_{oeff}$$

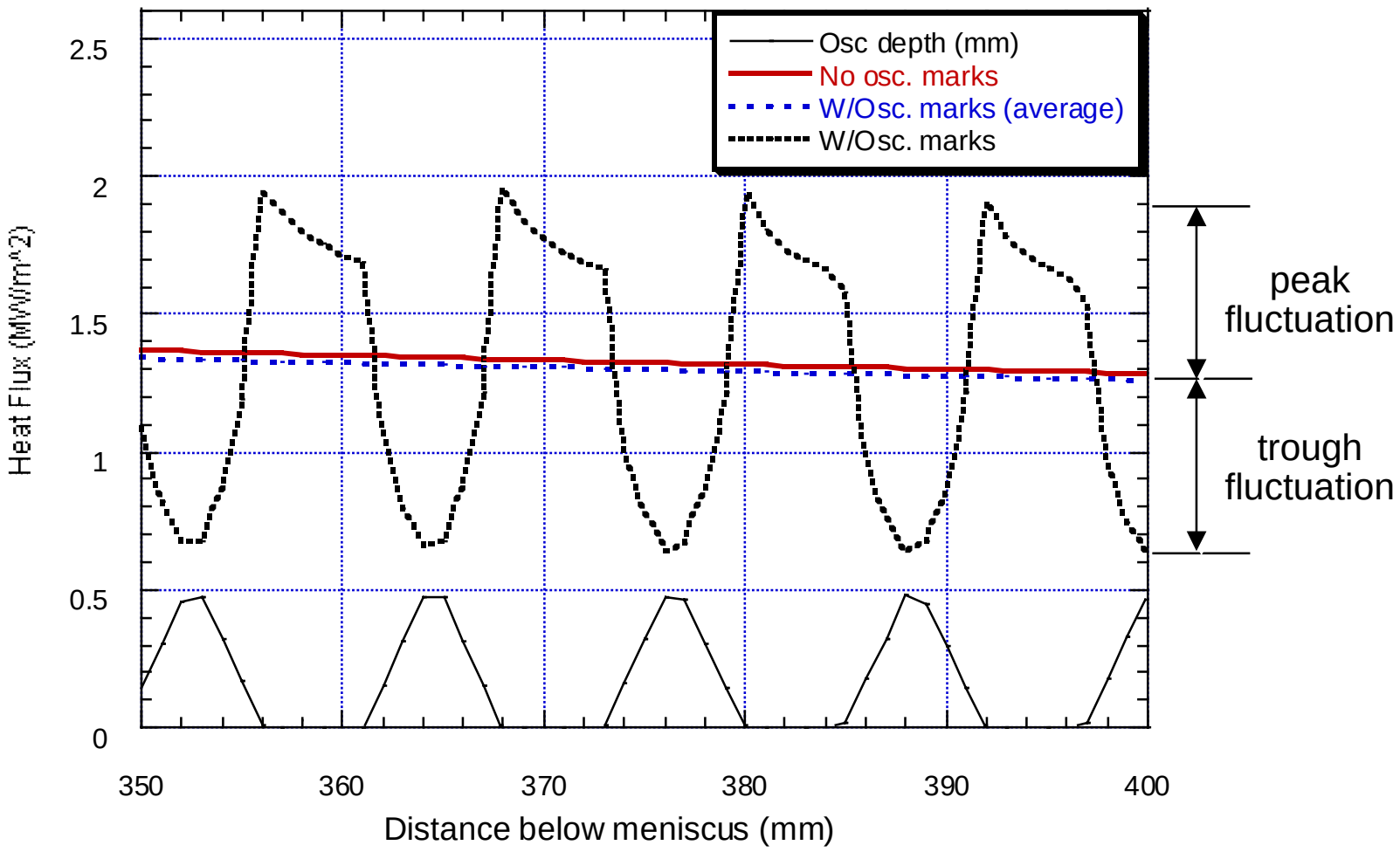
$$= \frac{L_{mark} d_{mark}}{\left(L_{pitch} - L_{mark}\right)\left(1 + \frac{d_{mark} k_{gap}}{k_{mark} d_{gap}}\right) + L_{mark}}$$

- ioscflag=1 (transient osc.thickness)

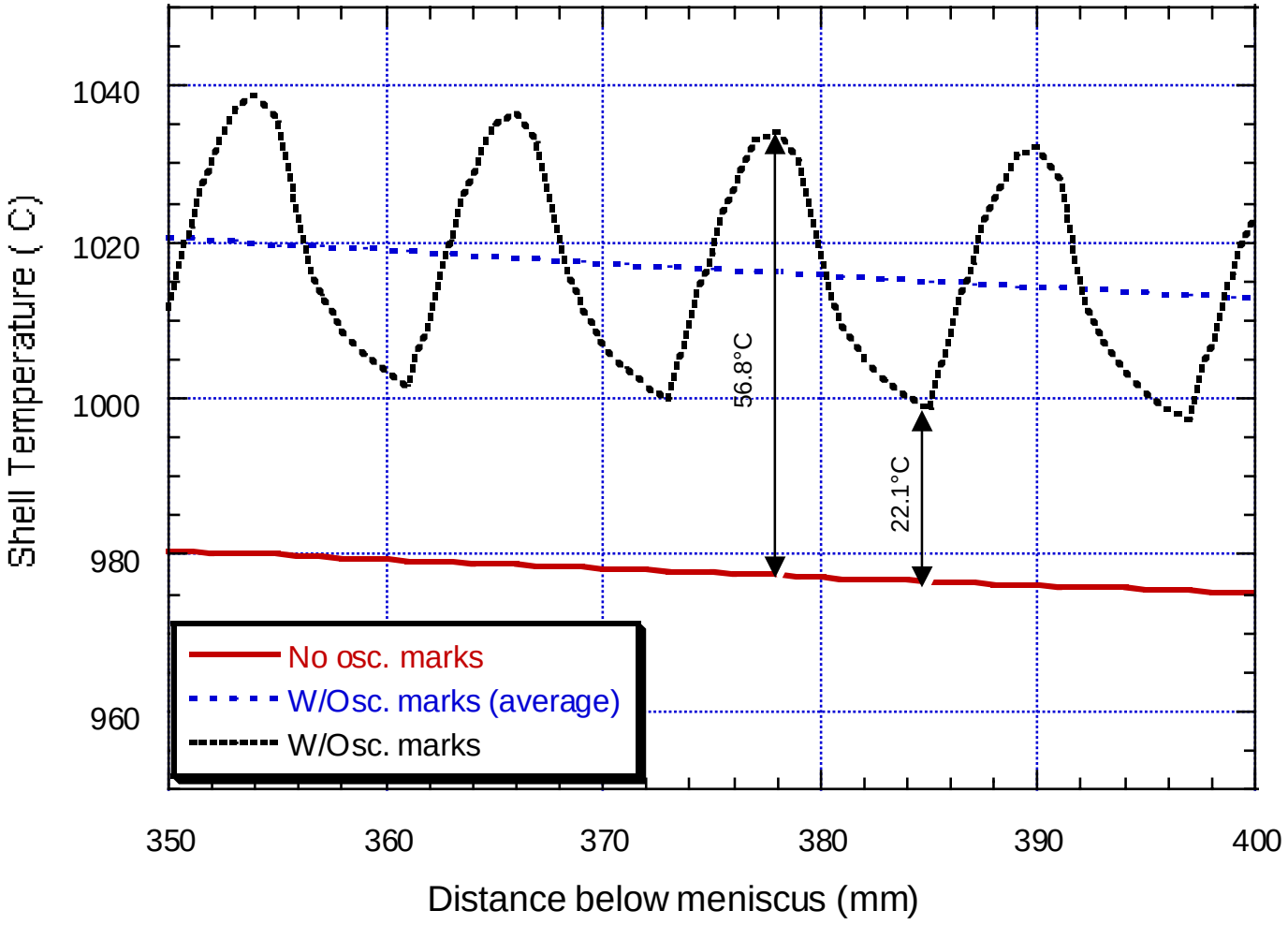
$$d_{osc} = f(z,t)$$



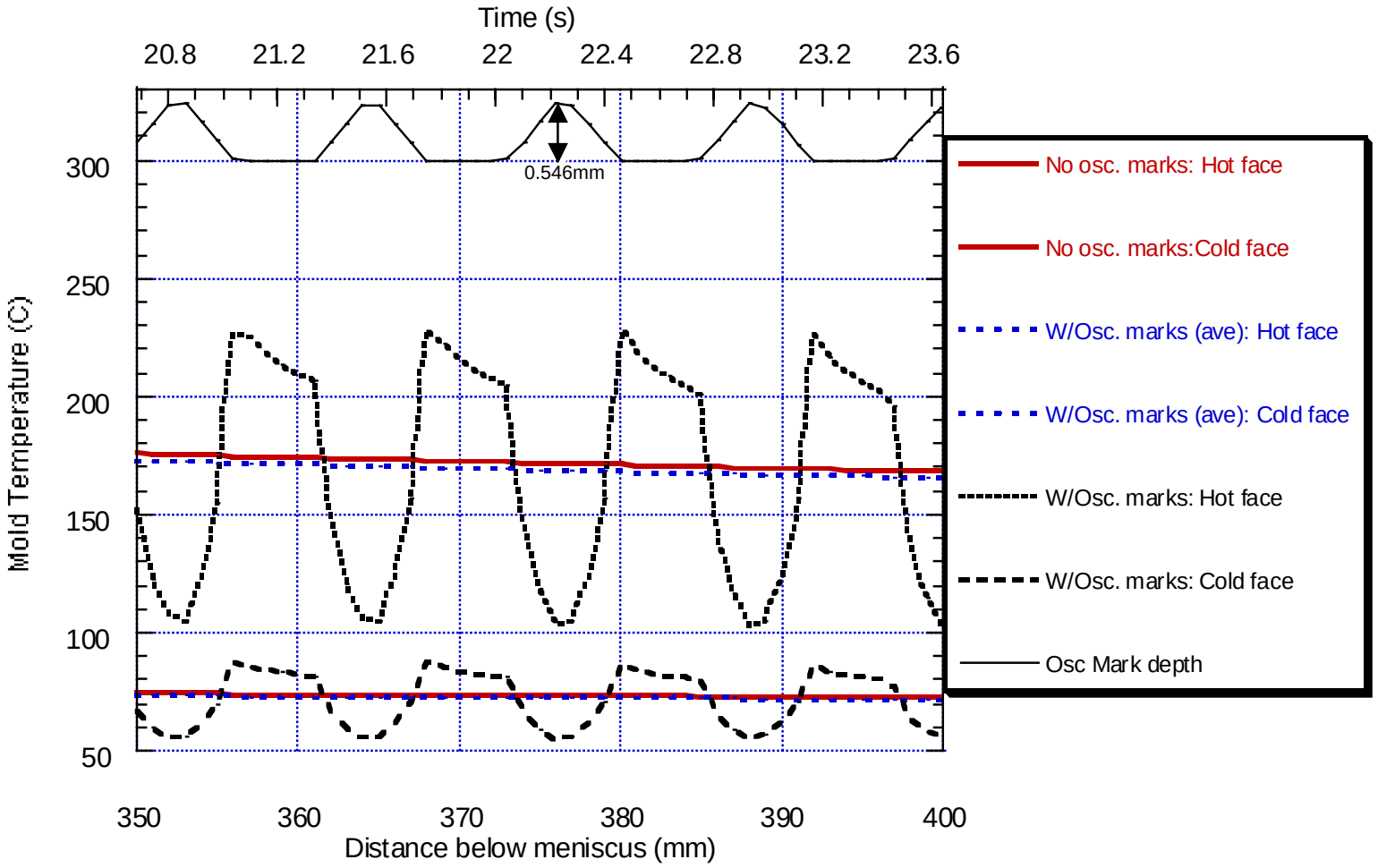
The Effect of Oscillation Marks on Heat Flux



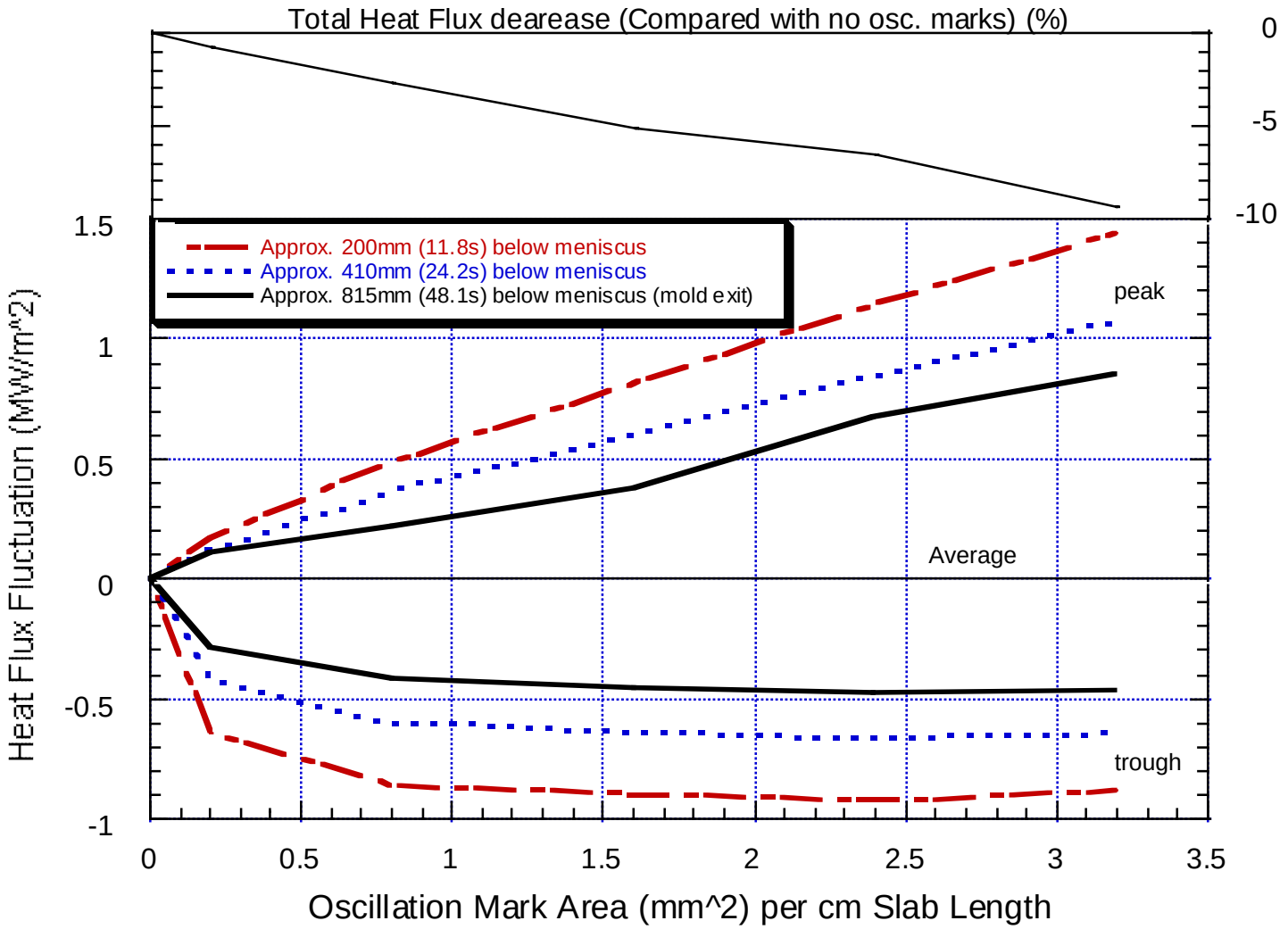
The Effect of Oscillation Marks on shell Temperature



The Effect of Oscillation Marks on Mold Temperature



Effect of Osc. Mark Area on Heat Flux Fluctuation



Oscillation Mark Model

- Oscillation marks have important effect on heat transfer in flux layers. In general, they:
  - impede heat transfer across the interface,
  - decrease shell thickness,
  - increase shell temperature,
  - decrease mold temperature.
- Specifically,oscillation marks cause fluctuation in heat flux, mold temperature and shell temperature, and very slight variation in shell thickness.
- This model can be used to interpret the thermocouple signals for on-line quality monitoring.

New Taper Model

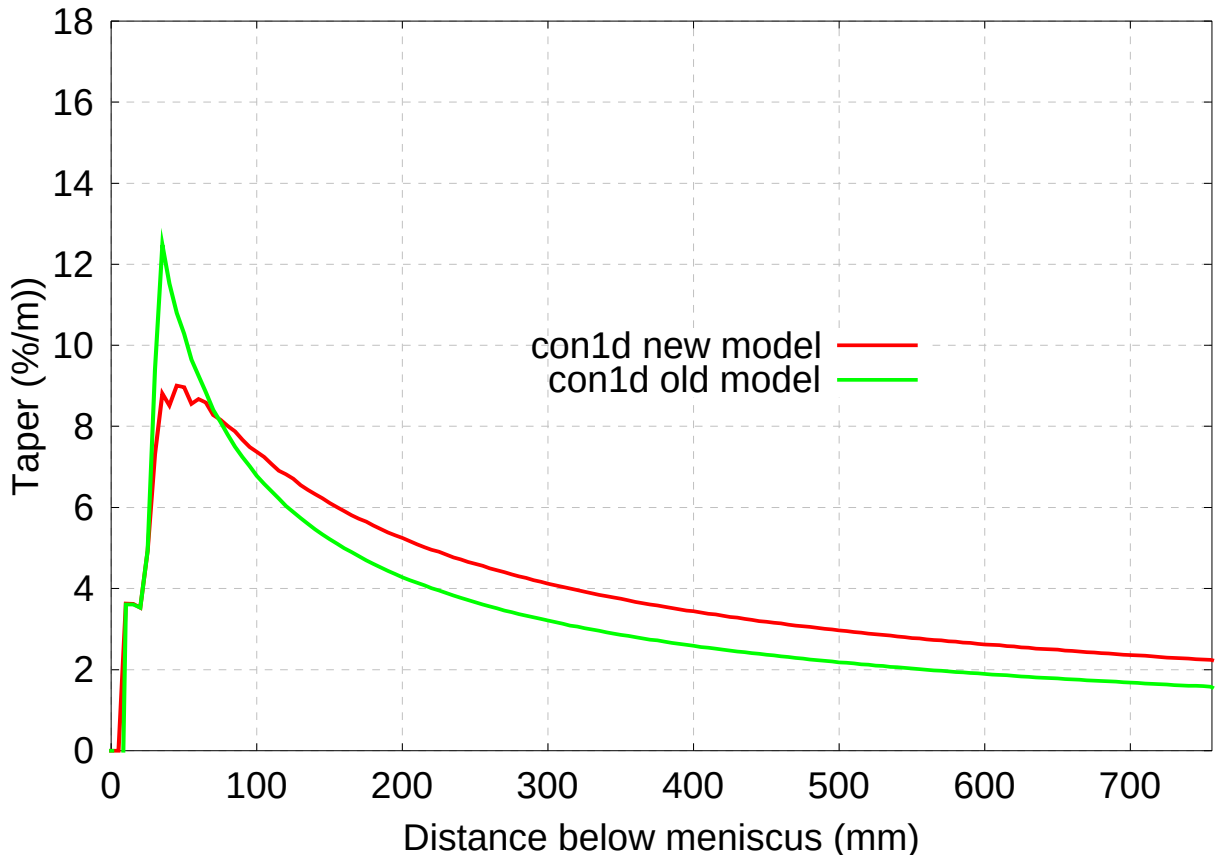
- Old Model:

$$\Delta W = \left(TLE(T_{sol}) - TLE(T_s)\right)\frac{W}{2}$$

- New Model:

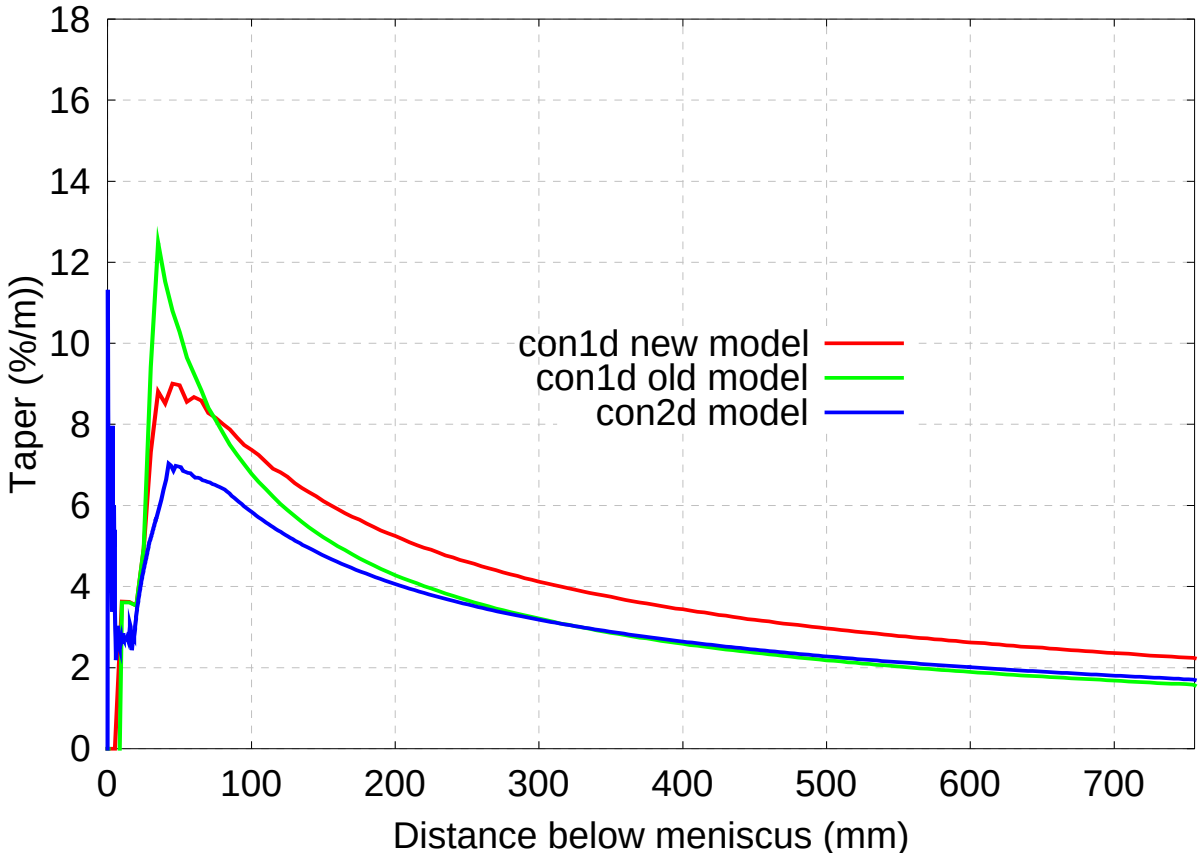
$$\Delta W = \left(\frac{1}{i}\right)_{i=solid\ nodes} \sum \left(TLE(Tnext(i)) - TLE(T(i))\right)\frac{W}{2}$$

Taper Model Comparison



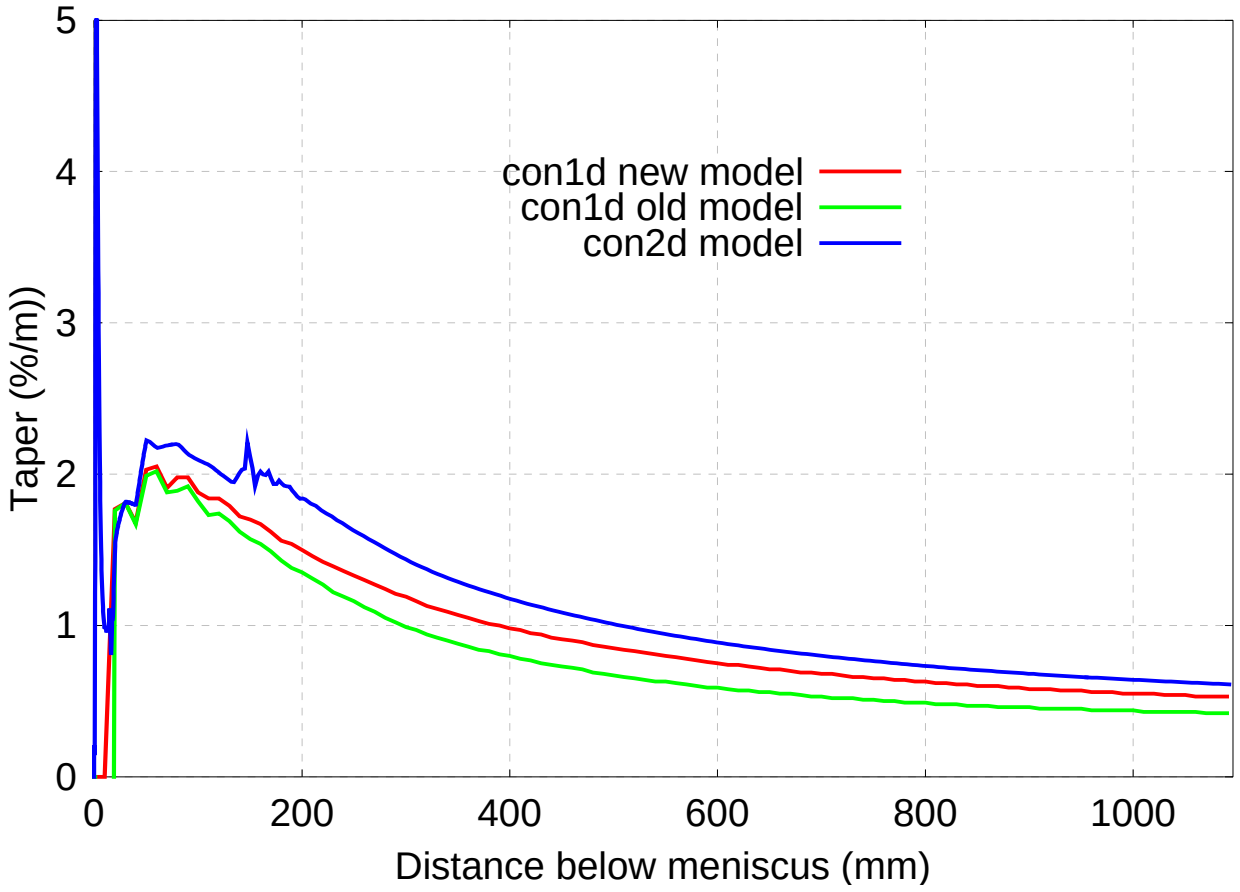
Taper Model Comparison

Heat removed from mold: 60MJ/m^2 (LTV Case)



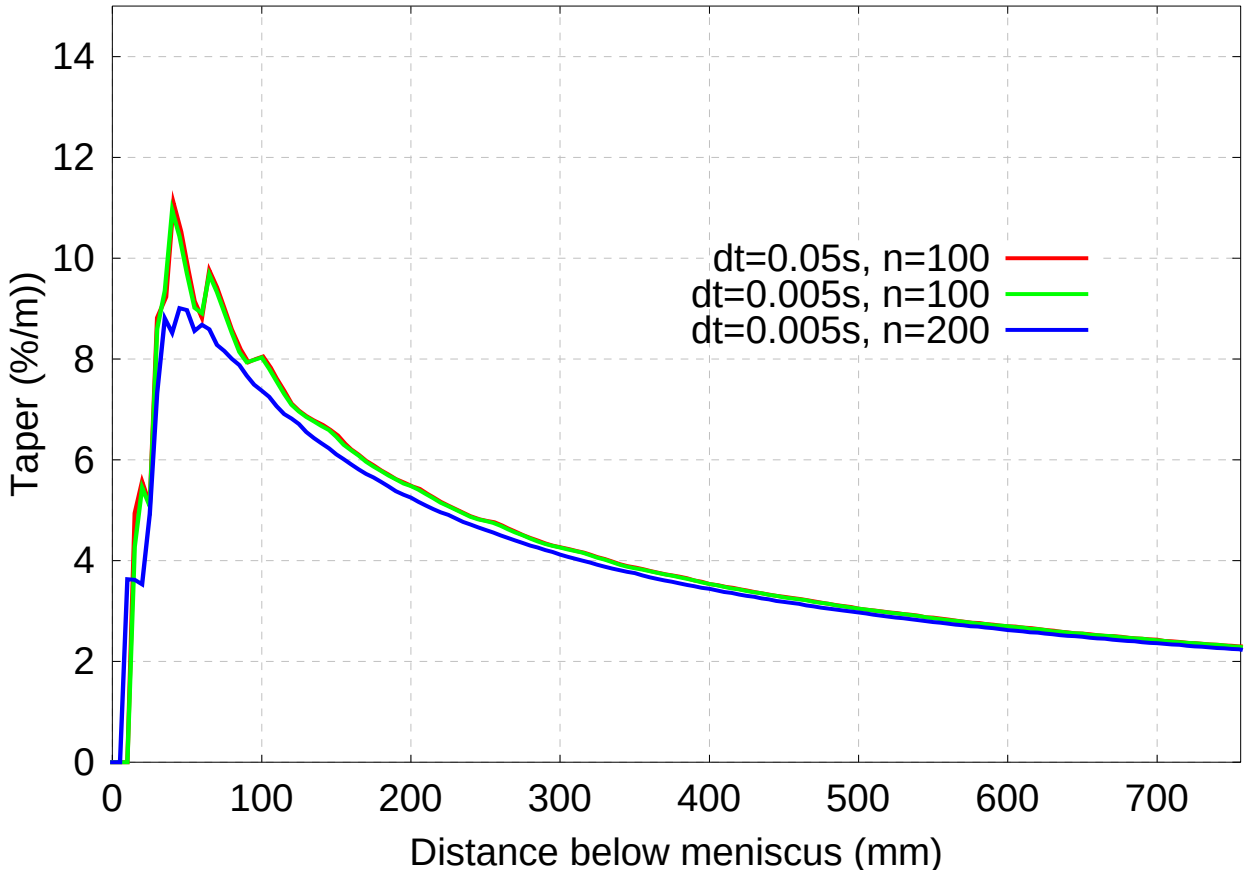
Taper Model Comparison

Heat removed from mold: 40MJ/m²



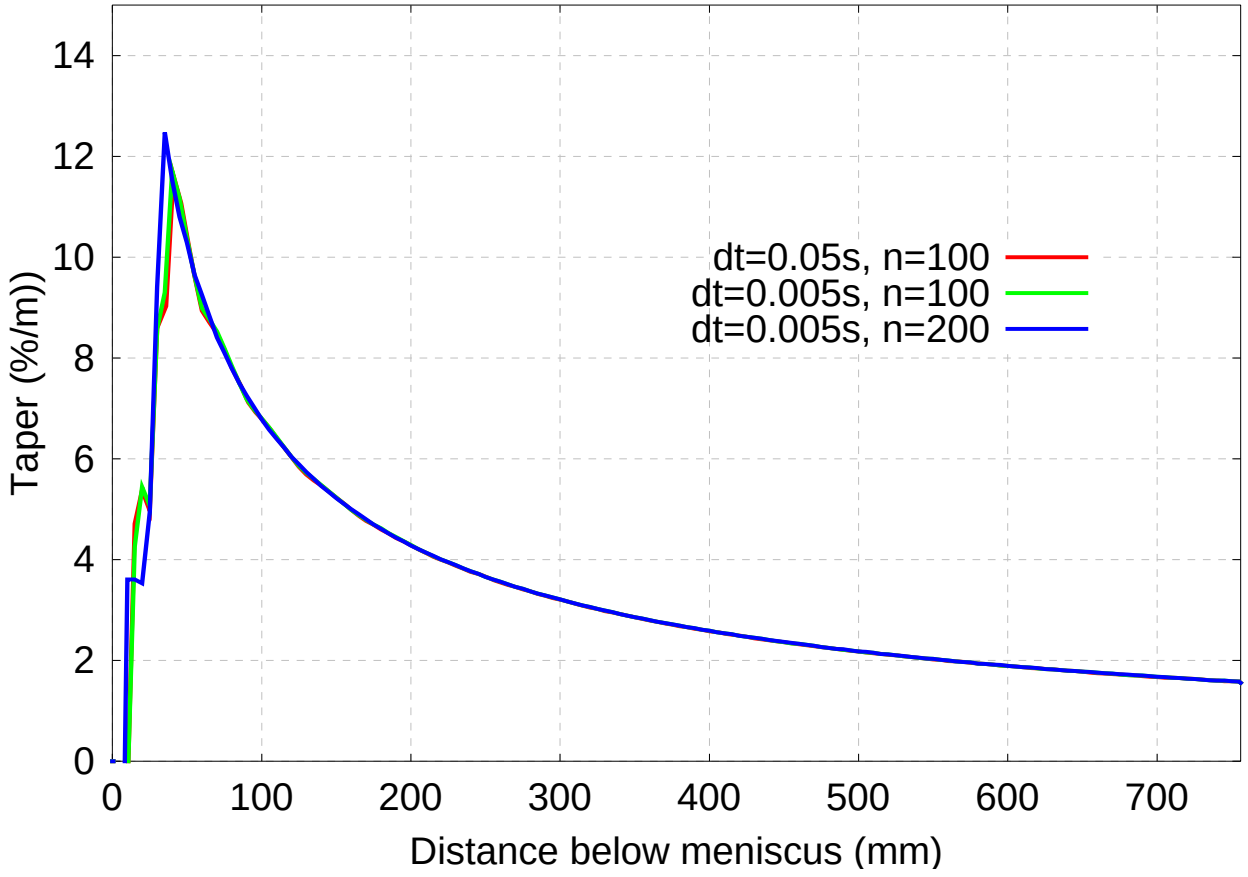
New Taper Model

(Mesh size comparison)



Old Taper Model

(Mesh size comparison)



Future Work

- The oscillation mark model still need to be compared with 2D simulation results using CON2D
- Input literature function to predict mold powder consumption and oscillation mark depth
- Study the effect of microstructure and segregation on shell growth and crack
- Extend model to predict crack susceptibility, critical shell thickness to avoid breakouts, and optimum taper as a function of steel grade and casting conditions
- Apply model to perform parametric studies