Annual Report

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CON1D User-friendly Interface

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Project Goals

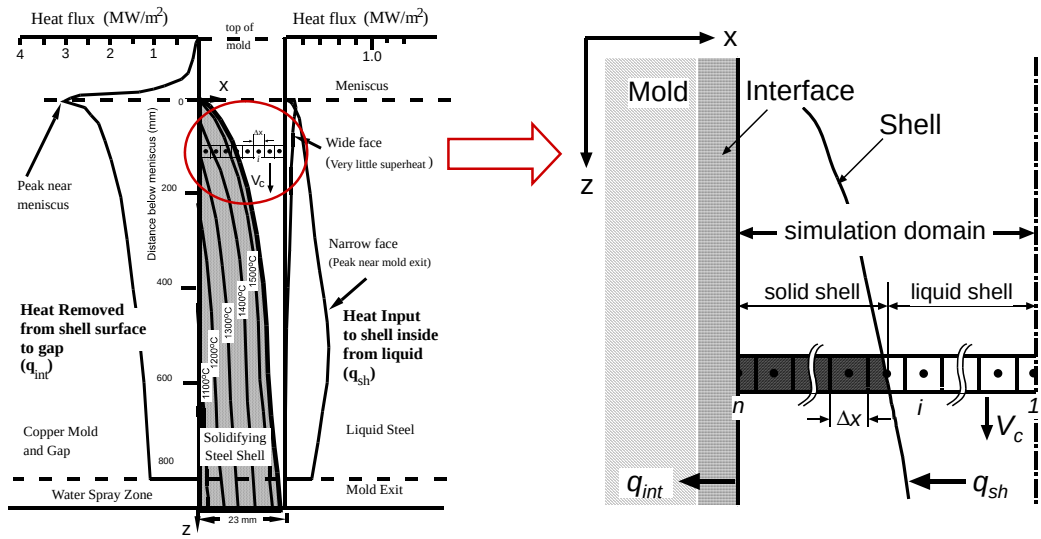
- Create a user-friendly interface for CON1D
- Target audience
  - Researchers
    - Graduate students
    - Industry
  - Casting operators
- Write inputs
- Run CON1D
- Read outputs

What is CON1D?

Heat Transfer Model of Steel Continuous Casting

Transient heat conduction model of shell

$$\rho_{steel} Cp^*_{steel} \frac{\partial T}{\partial t} = k_{steel} \frac{\partial^2 T}{\partial x^2} + \frac{\partial k_{steel}}{\partial T} \left(\frac{\partial T}{\partial x} \right)^2$$



Model includes➔ *mold, interface, shell*

CON1D Model Applications

Model Prediction	Validation
• Heat flux variation • Mold Temperature	Thermocouples embedded in mold wall
• Cooling water temperature increase	Water temperature rise / flow rate
• Shell thickness	Breakout shell or tracer element
• Slag layer thickness	Slag samples taken from mold wall
• Shell temperature	Optical pyrometers, thermocouples in the strand
• Ideal taper	Friction signal; defects
• Mold friction and lubrication state	Friction signal
• Slag microstructure	Crystalline vs. glassy
• Slag shear/fracture	Transient temperature variation
•Metallurgical length	Whale formation!

Previous Input Interface

- Text editor to change the input file

example.inp - Notepad

File Edit Format View Help

```
                CON1D-9.7 Slab Casting Heat Transfer Analysis
                University of Illinois, Brian G. Thomas, 2009

                                Example Input Data (NU6-146)

 #1 Parameters to update every call
 //CASTING CONDITION:
           3        Number of time-cast speed data points
                    (If=1, constant casting speed)
                    Next 2 lines contain time(s) and vc(m/min) data points
    0. 300. 320.
 3.70 3.70 4.70
   1553.000         Pour temperature (C)
   100.0000         Distance of meniscus from top of mold (mm)
   150.0000         Nozzle submergence depth (mm)

           0        New simulation or Restart (0=new; 1=restart)
   15000.00         Max. simulation length (must > z-distance)(mm)

           0        Calculate mold and interface (=0 flux casting, or =2 oil casting )
                    or enter interface heat flux data starting at meniscus z=0 (=-1)
                    or enter avg. mold flux (=-2), or enter cooling water temp. increase (=-3)
           9        Number of zmm and q data points (if above = -1)
                    Next 2 lines contain zmm(mm) and q(kw/m2) data
     0.00    40.00   100.00   200.00   300.00   410.00   550.00   850.00   950.00
  5360.00  4000.00  3410.00  2600.00  2350.00  2340.00  2310.00  2000.00  2000.00
    2.4243    2.4243  2.3  0.07  0.4  Average mold heat flux (MW/m^2) and tuning parameters q_fac, tc_fac, q_n(if above =-2)
   -9.8800   -9.8800     Mold cooling water temp. increase (Deg C)(if above =-3)
  -1                Running mode (0=stop right now; -1=continue to run; positive integer ts
                    = run the program for ts seconds.

 //SPRAY ZONE VARIABLES:
   8.700000         Minimum convection heat trans. coeff. (natural) (W/m^2K)
 right side (inside radius):
   25.00000         Water and ambient temperature after spray zone(Deg C)
                    spray zone condition:(heat tran.coeff.funct:h=A*C^R*W^n(1-bT))
                    (Nozaki Model:A*C=0.3925,n=0.55,b=0.0075)
   1.570000         A(0=off)
  0.5500000         n
```


Previous Output Interface

- Gnuplot scripts to graph outputs

gnuplot

File Plot Expressions Functions General Axes Chart Styles 3D Help

Replot Open Save ChDir Print PrtSc Prev Next

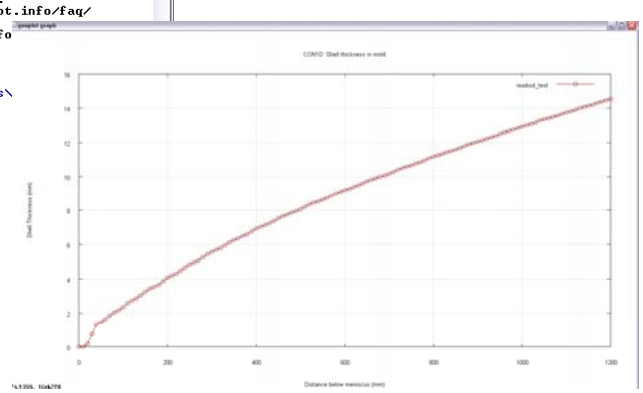
```
        G N U P L O T
        Version 4.2 patchlevel 2
        last modified 31 Aug 2007
        System: MS-Windows 32 bit

        Copyright (C) 1986 - 1993, 1998, 2004, 2007
        Thomas Williams, Colin Kelley and many others

        Type `help` to access the on-line reference manual.
        The gnuplot FAQ is available from http://www.gnuplot.info/faq/

        Send bug reports and suggestions to <http://sourcefo
plot>

Terminal type set to 'windows'
gnuplot> cd 'C:\Documents and Settings\Hemanth\My Documents\
arch\Project\gnuplot_tests'
gnuplot>
gnuplot> call 'g.shr' 'readout_test' 'filews_test'_
```



Platform – Excel 2003

- Excel is widely used
- Graphing tools are built in
- Easy to update interface for future students

Color Scheme

Home page buttons color scheme

Write Input File	Purple Buttons – Suggests the next logical step
Final Data Check	Green Buttons – Completed step
Casting Condition	Yellow Buttons – Page did not pass data check

Cells color scheme

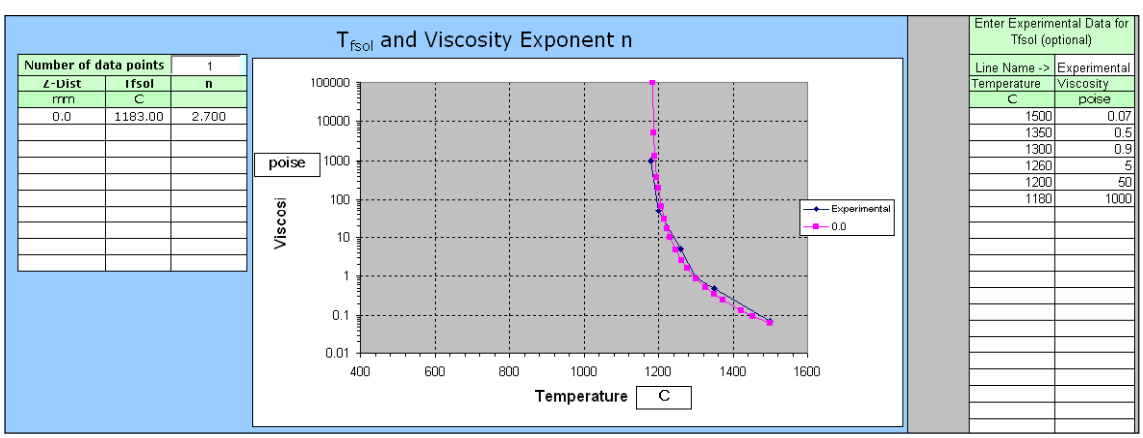
	White Cells - Where User can enter data
	Green Cells - Parameter description or parameter title
	Yellow Cells - Parameter title / description with missing data
	Light Blue Cells - Output data from output files
	Dark Blue Cells - Section or Worksheet Titles
	Cyan Cells - Section block background

Input Features

- Graphs for inputs
- Use of spray tables
- Preset grade tables
- Customizable units
- Parameters are further explained in comments or with pictures on the page

Visualizing input data

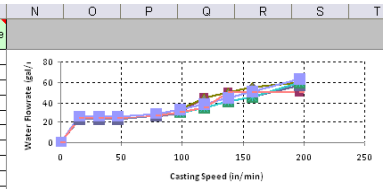
- Example: slag viscosity data:
  Automatic graphing of viscosity curves before running simulation
- Also plots measured values for comparison

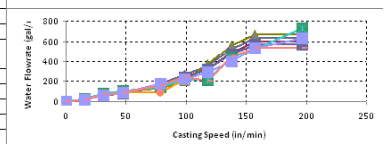


Spray Tables

- Once spray tables are setup, can use the table to update water flow rate values in the spray zones.
- Can also view the spray table flow rates in graphs

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	# Patterns	8	Casting Speed	Pattern1	Pattern2	Pattern3	Pattern4	Pattern5	Pattern6	Pattern7	Pattern8	znames	rows/zone
2	# Speeds	10	0	0	0	0	0	0	0	0	0	ZMSB	2
3	# Zones	10	15.7	26	24	26	23	26	26	26	24	ZMSB	2
4			31.5	26	24	26	23	26	26	26	24	ZMSB	2
5			47.2	26	24	26	23	26	26	26	24	ZMSB	2
6	Speed Units		70.7	29	27	29	26	29	29	29	27	ZMSD	2
7	in/min	m/sec	98.4	33	31	33	30	30	33	33	31	ZMSB	2
8			118.1	45	45	45	35	35	39	39	35	ZMSB	2
9	ft/min	m/min	137.8	50	50	50	41	41	45	45	50	ZMSB	2
10			157.5	55	50	55	46	46	51	51	50	ZMSB	2
11			196.8	60	50	60	57	60	63	63	50	ZMSB	2
12	Flowrate Units		0	0	0	0	0	0	0	0	0	Z1AC	10
13	gal/min	L/min	15.7	20	19	21	18	23	20	17	19	Z1AC	10
14			31.5	70	66	74	63	81	70	59	66	Z1AC	10
15			47.2	92	86	98	83	106	92	92	86	Z1AC	10
16			78.7	172	162	130	155	143	92	172	162	Z1AC	10
17	CLICK if spray table has been updated		98.4	264	248	200	238	219	222	222	248	Z1AC	10
18			118.1	349	320	370	314	209	289	289	205	Z1AC	10
19			137.8	528	496	560	475	437	400	400	446	Z1AC	10
20			157.5	634	596	672	571	525	533	533	536	Z1AC	10





Preset Grade Table

- Users can preset the compositions of commonly used grades.
- The interface will automatically enter the compositions for a simulation by choosing a preset grade

Home

Grades 4

Update Preset Grades

Steel Slab Properties

Grade Name	% C	% Mn	% S	% P	% Si	% Cr	% Ni	% Cu	% Mo	% Ti	% Al	% V	% N	% Nb	% W	% Co
Steel 1	0.0470	0.4800	0.0010	0.0260	0.3900	16.7100	0.2000	0.1000	1.0000	0.0000	0.0030	0.0260	0.0560	0.0100	0.0000	0.0200
Steel2	0.0470	0.4800	0.0010	0.0260	0.3900	18.0000	0.2000	0.1000	1.0000	0.0000	0.0030	0.0260	0.0560	0.0100	0.0000	0.0200
Steel3	0.1000	0.4800	0.0010	0.0260	0.3900	17.0000	0.2000	0.1000	1.0000	0.0000	0.0030	0.0260	0.0560	0.0100	0.0000	0.0400
Steel4	0.0470	0.4000	0.0010	0.0260	0.3900	20.0000	0.2000	0.1000	1.0000	0.0000	0.0030	0.0260	0.0560	0.0100	0.0000	0.0200

Customizable Units

- A unit set for the data in the inputs and outputs can be chosen by users.
- The custom unit set can incorporate a mixture of metric and British units.

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Update Units

Unit set Names				
Metric		British		Custom

Casting Condition						
Name	Metric	Factor to Multiply by to Convert to Con1D units	British	Factor to Multiply by to Convert to Con1D units	Custom	Factor to Multiply by to Convert to Con1D units
Temperature	C	1.00000, 0	F	0.55555, -32	Custom	1.00000, 0
Distance	mm	1	in	25.4	Custom	1
Heat Flux Data Points	(kW/m^2)	1	Btu/(hr*ft^2)	0.003154	Custom	1
Average mold heat flux	(MW/m^2)	1	Btu/(hr*ft^2)	0.000003154	Custom	1
Mold cooling water temp. increase	C	1.00000	F	0.55555	Custom	1.00000
Super Heat Flux	(kW/m^2)	1	Btu/(hr*ft^2)	0.003154	Custom	1

Output Features

- Easy to read in and graph outputs
- Ability to select which outputs to read
- Plot two runs on the same graph
- Personalize graph views
  - Cannot delete a series of data

Order of Tasks

1. Open Excel file
2. Enter run information on home page
3. Edit inputs
4. Final data check
5. Write input file
6. Run CON1D
7. Read run time messages
8. Read outputs

Directory Notes

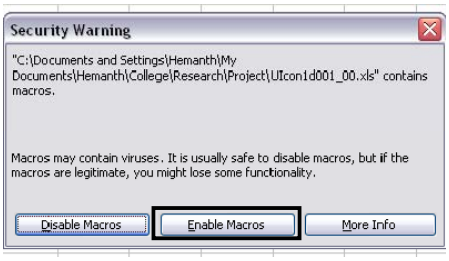
- Start with CON1D9.7.1.exe in the same folder as the excel interface.
- The excel interface will write the input files into the working directory (which is the directory the excel interface file is located). The outputs will be written into this directory by CON1D and then can be read into the interface for viewing.
- The input and output files need to be in the same folder as the excel interface file to read in and graph the output data

Starting the Interface

- You may need to "enable macros" upon startup of the .xls file. Usually, this is solved by answering "Enable Macros" to prompting. If you have macros disabled, you may have to change security settings
- Starting the interface and enabling macros is described with pictures in the next three slides

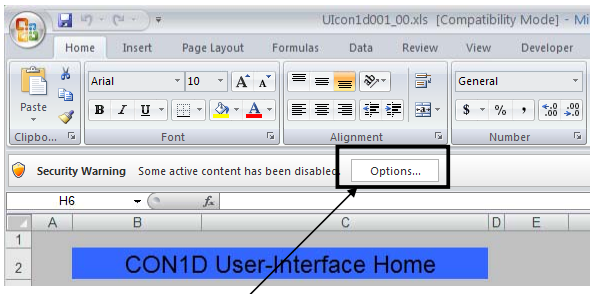
Starting the Interface Office 2003

- Enable macros at start by choosing “Enable Macros”

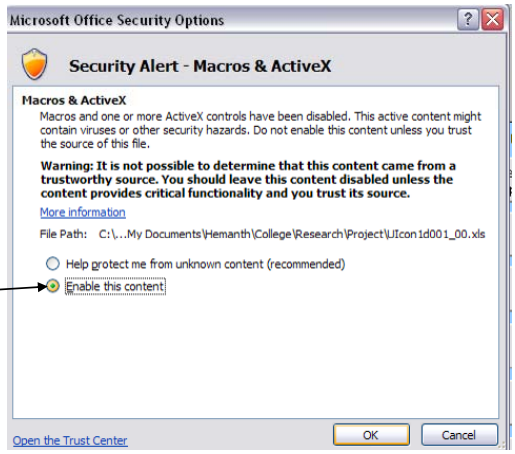


- If security setting is too high:
  file will not open and/or macros will not run
- change security settings by follow steps
  - **Tools** -> **Macro** -> **Security…**
  - Choose Either “**Medium**” or “**Low**”
  - Reopen interface file and Enable Macros

Starting the Interface Office 2007

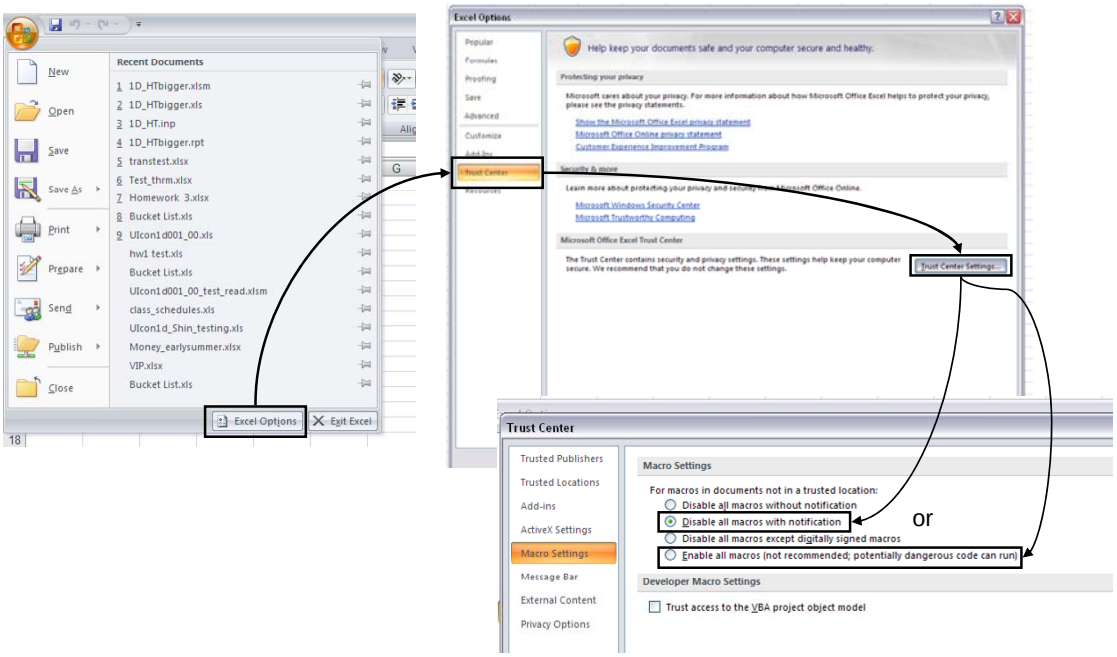


Click on the "**Options**" button to enable macros



Select "**Enable this content**"

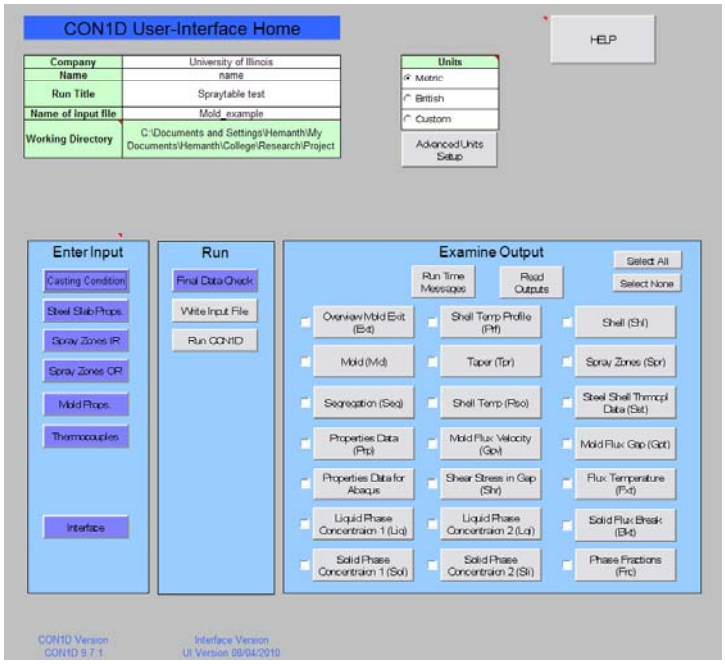
Changing Security Settings in Office 2007



Homepage

- Run information
- Links to all input and output pages
- Buttons for writing input file, and running CON1D

Homepage



Inputs Organization

- Casting Condition
  - Casting conditions
  - Simulation parameters
- Steel Slab Properties
  - Slab geometry
  - Steel properties
- Spray Zones
- Mold Properties
  - Mold cooling water parameters
  - Mold water properties
  - Mold geometry
  - Mold coating/plating thickness
- Thermocouples
- Interface
  - Mold flux properties
  - Interface heat transfer properties

Demonstration

Conclusions

- A new user interface for the CC heat-flow modelCON1D has been created. This graphical interface includes many user-friendly features that are a great improvement over the previous text-based interface used.
- Graphs in the input parameters helps users visualize data they are entering.
- A preset grade table enables users to setup compositions of common grades and to choose from the list for later runs.
- The new interface can automatically change water flow rates for a simulation based on 1) data provided in spray tables, 2) casting speed, and 3) spray pattern choices.
- The interface offers fully customizable units to let users choose metric, British or a mix of both unit sets.
- Initial feedback from user evaluations was positive and resulted in improvements.

Acknowledgements

- Professor Brian G. Thomas
- Students in the Metals Processing Simulation Laboratory