

# OPTimal CASTing–User Manual–1

Urlau, Nallathambi, Specht

Urlau Innomanagement GmbH  
Otto von Guericke University Magdeburg

*info@urlau-innomanagement.com, ashok.nallathambi@ovgu.de, eckehard.specht@ovgu.de*

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CASTing SIMulation software (CASTSIM) contains 5 folders which are placed inside the main folder known as **CSW**.

- **Grade Data Bank** – Information about existing steel grades and its casting parameters
- **Material Data Bank** – Existing steel grades material properties
- **Programs** – Software program for running simulations
- **Settings** – Contains default and user defined simulation settings
- **Simulations** – Simulation results are stored in this folder

# Grade Data Bank Folder

Grade Data Bank Folder contains following information about the steel grade:

- Grade number (*Grade\_Number*): eg: 2645
- Grade type (*Grade\_Type*): eg: C45
- Cooling mode (*Cooling\_mode*): Five different cooling modes can be assigned: Ultra mild, Mild, Medium, Strong, and Others
- Water flow rate (*Water\_flow\_rate*): Amount of water flow rate in different zones:(Zone 1,Zone 2a,Zone 2b,Zone 3a,Zone 3b) in Litre per meter
- Casting speed (*Vc\_target*)
- Casting temperature (*T\_init*)

File *Steel\_Grade\_Data.mat* contains a structured array *Steel\_reciepes\_SC*

File *Grade\_Data\_Read.m* is for generating *Steel\_Grade\_Data.mat* from *Casting Paramters.xlsx*

Material Data Bank Folder contains several sub-folders of material properties of steel grades. eg. 2645\_C45.

Within each steel grade folder, following text files contain temperature dependent material properties:

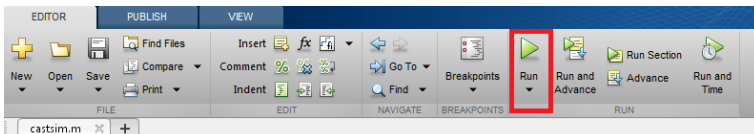
- Density in  $\text{g/cm}^3$  (2645\_density.txt)
- Enthalpy in J/g (2645\_enthalpy.txt)
- Phase fractions (2645\_phases.txt)
- Specific heat capacities (2645\_specific\_heat.txt)
- Thermal conductivity (2645\_thermal\_conduct.txt)

# Programs Folder

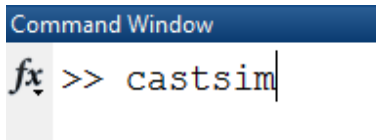
Program folder contains executable program file `castsim.m`. It contains all the necessary matlab programs to control/perform casting simulations. `Solver_new.m` contains finite element subroutines to solve the heat transfer during casting process.

To launch the CASTSIM main output window

- 1 Open the file `castsim.m` and press *RUN* button



- 2 Type '`castsim`' in matlab command window



# Settings Folder

Settings folder contains several user-defined simulation settings and default settings in \*.mat files.

Default\_Settings.mat is the completely initialized default settings.

Any settings file contains following parameters which controls the simulation:

- Mold parameters
- Secondary cooling parameters
- CCM(continuous casting machine) nozzle parameters
- Simulation related parameters

## Default Settings

It has two categories of variables. (a) **Grade dependent** default settings such as casting speed, casting temperature, cooling mode, etc. (b) **Grade independent** default settings such as mold cooling, and secondary cooling parameters.

# Simulations Folder

Simulations folder currently running simulation results and already completed results.

It can have several sub folders with the name in the form of grade number\_grade type.

With in each results folder following categories of \*.mat files might present.

- Material.mat
- Process\_Parameters.mat – all set of parameters used in that particular simulation
- DB0.mat, DB1.mat, DB2.mat, etc. – result database files

## DB\*.mat

Each database file contains computed temperature values in each FE nodes, time, and axial distance from meniscus. It also contains IP(integration point) data which are necessary for computing temperature at next time step.



# Castsim Main Window

The screenshot displays the CASTSIM 1.0 software interface. At the top, a red box highlights the navigation tabs: **Main Settings** (1), **User Settings** (2), **Results** (3), and **New Grade** (4). The **Main Settings** tab is active, showing the following sections:

- Steel Grade Definition:** Steel Number is 1015 (selected from a list including 1015, 1035, 1037, 1040, 1045). Steel Type is S235JR.
- Casting & Cooling Parameters:** Casting Speed is 2.38 m/min. Cooling Mode is Strong. Water Flow is 50 L/m. Casting Temperature is 1567 degC. Zone I is 50, Zone II is 75, and Zone III is 36.
- Simulation Settings:** Simulation Folder is 1015\_S235JR. Select Predefined Settings is Default\_Settings (selected from a list including 4111-11SMn30, 4904-11SMnPb30, 4905-6-11SMnPb37, 6138-38MnVS6, Default\_Settings, S1).
- Material Dependency:** A radio button is selected for ON.
- Properties:** Liquidus Temperature is 1530.01 degC. Solidus Temperature is 1510.51 degC. Latent heat is 242.8 J/g. Thermal Conductivity is set to a dropdown menu.

On the right side of the Properties section, there is a graph of Thermal Conductivity [W/mK] versus Temperature [degC]. The curve starts at approximately 55 W/mK at 0 degC, decreases to a minimum of about 28 W/mK at 900 degC, and then increases to about 38 W/mK at 1500 degC, with a small peak around 1400 degC.

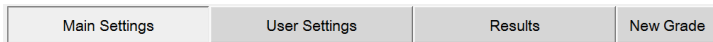
At the bottom right, there is a **RUN Simulation** button. The bottom of the window features logos for Otto von Guericke University Magdeburg, LEH STÜHL, SWISS STEEL, and Otto von Guericke University Magdeburg.

# Castsim Main Window

CASTSIM main window has 4 different Tabblings [9]:

- ① **Main Settings** – Simplified compact level of running simulations
- ② **User Settings** – Detailed elaborate level of running simulations and possibility to save the settings for future simulations
- ③ **Results** – Postprocessing the simulated data in the form of line and contour graphs
- ④ **New Grade** – To input new grade material and casting parameters into existing data bank

While clicking each tab, the elements are replaced with completely new one.



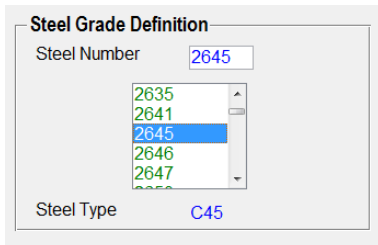
# Tab 1–Main Settings

Main Settings Tab has 5 panels and one action button.

## Panels

(a) Steel grade definition, (b) Casting & cooling parameter, (c) Simulation settings, (d) Material dependency, and (e) Properties

### Panel (1a) – Steel grade definition



The screenshot shows the 'Steel Grade Definition' panel. It contains two input fields: 'Steel Number' and 'Steel Type'. The 'Steel Number' field has a text input with '2645' and a dropdown list below it showing a list of steel grades: 2635, 2641, 2645 (highlighted), 2646, 2647, and 2650. The 'Steel Type' field has a text input with 'C45'.

Steel grade from data bank can be selected in 2 ways

- 1 Typing the grade number in Steel Number \* (eg. 2645) followed by Enter key ↵
- 2 Selecting the grade from the list shown

\* If the grade does not exist, warning window will appear and default grade will be selected automatically.

## Panel (1b) – Casting & cooling parameter

no input, just displaying casting recipe

Casting & Cooling Parameters		
Casting Speed [m/min]	Cooling Mode	Strong
2.38	Water Flow [L/m]	
Casting Temperature [degC]	Zone I	50
1527	Zone II	75
	Zone III	36

- Casting speed and temperature for the selected grades are shown
- Default cooling mode assigned for grade and its water flow rates are shown. Table Shows the standard water flow in Litre/meter.

Mode	Zone 1	Zone 2	Zone 3
Ultra mild	33	43	13
Mild	33	55	13
Moderate	40	60	13
Strong	50	75	36
Other	X	X	X

When Grade dependency is deactivated, the parameters change according to settings selected.

# Panel (1c&d) – Simulation setting & Material dependency

## Panel (1c) – Simulation settings

**Simulation Settings**

Simulation Folder: 2645\_C45

Select Predefined Settings

Default\_Settings

4111 - 11SMn30  
4904 - 11SMnPb30  
4905-6-11SMnPb37  
6138-38MnVS6  
Default\_Settings  
S1

**Material Dependency**

☒ ON ☐ OFF

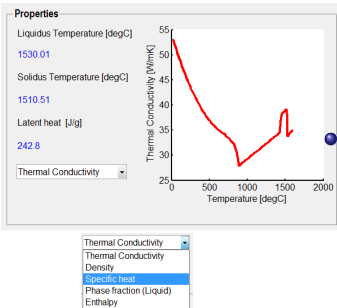
- Selected grade number and type is the name of the new simulation folder. User can also type their own.
- Universal default setting is always 'Default\_Setting'
- User choose any other settings ( if the user defined setting has been created previously)
- By default 'Default\_Setting' is selected as User setting

## Panel (1d) – Material dependency

- ON – Selected grade's casting parameters are considered as default
- OFF – Default\_Setting & User\_Setting will have corresponding casting parameters.

In both the cases, parameters in User\_Setting will be used for the simulation

# Panel (1e) – Properties




- Liquidus ( $T_L$ ) and Solidus ( $T_S$ ) temperatures and Latent heat ( $L$ ) are independent of temperatures. These values are extracted from the phase fraction and enthalpy data.
- Thermal conductivity ( $k$ ), specific heat capacity ( $C_p$ ), density ( $\rho$ ), liquid phase fraction ( $f_l$ ), and enthalpy ( $h$ ) are function of temperature. Selecting from the drop-down option, graphical display can be changed.

$$\begin{aligned}
 L_1 &= h(T_L) - h(T_S) \\
 L_{corr} &= C_{pL}(T_L - T_S) - \frac{(C_{pL} - C_{pS})}{(T_L - T_S)} \frac{(T_L^2 + T_S^2 - 2T_L T_S)}{2} \\
 L &= L_1 - L_{corr}
 \end{aligned}$$

where the subscript  $L$  and  $S$  are liquid and solid state.

# Running Simulation

In the main window, **RUN Simulation** button is used to start the simulation.

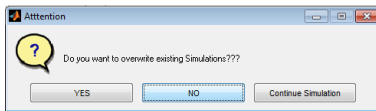
An orange rectangular button with the text "RUN Simulation" in black.

6 % Completed : 0.32 m reached

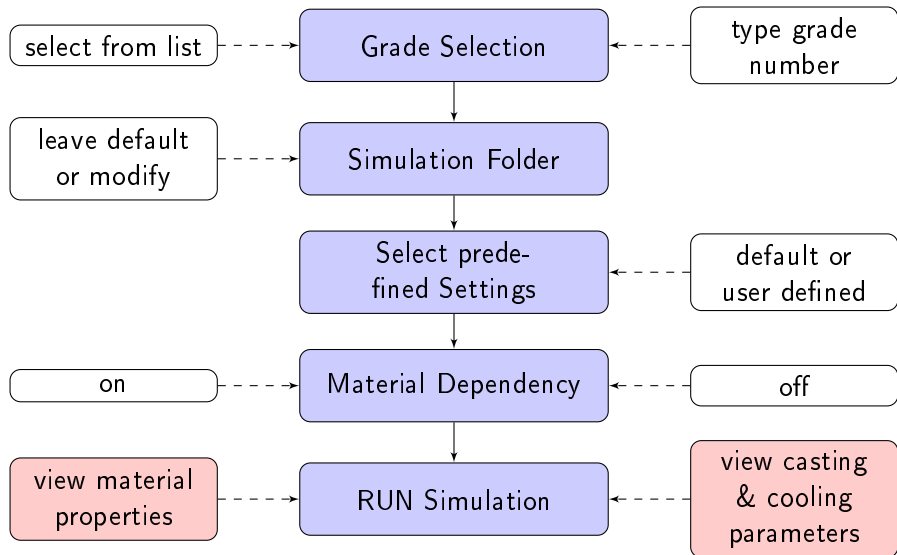
An orange rectangular button with the text "STOP Simulation" in black.

- After clicking RUN Simulation button, the display changes in to **STOP Simulation** button
- The status of the simulation will be displayed on the left side.
- Simulation can be interrupted by clicking **STOP Simulation** button or typing **Strg** **c** in matlab command window. Also by **Strg** **Pause** **Untrbr**.

After an interruption, it is possible to continue the simulation or start a fresh new simulation.



# Main Window – Flowchart





**default**, **user**, and **present** are the three variables (data type:structure) which store casting process and simulation parameters. All these three structures, contain a variable *Grade\_depend* which is also a structure, holds information about the particular grade.

- *default* : Universally set default variables. However, *Grade\_depend* changes with grades.
- *user* : User can input the parameters and store as particular settings.
- *present* : It can contain either default or user information which is the finally used variable for the simulation. Its *Grade\_depend* depends on the choice of the material dependency.

*Grade\_depend* contains (a) Cool\_Mode, (b) Cool\_mode\_Value, (c) WFR\_Lm3, (d) Casting\_speed, (e) Init\_Temp, (f) Grade\_Number, and (g) Grade\_Type. eg: Strong, 4, [50 75 36], 2.38, 1556, 2615, and C15.

# Main Window – Variables Flowchart

