

# MAGMASOFT®

Version 4.4

MAGMAplug

Simulation of Melt Flow from Ladle with Plug



Manual

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# 1 MAGMAplug

## 1.1 Introduction

Mold filling simulation requires information about the way the melt flows into the mold. You must define this boundary condition in the simulation setup of MAGMASOFT® in the 'filling depends on' field ('filling definitions' window).

The option MAGMAplug enables you to calculate this boundary condition automatically, based on the geometries and parameters of ladle and plug.

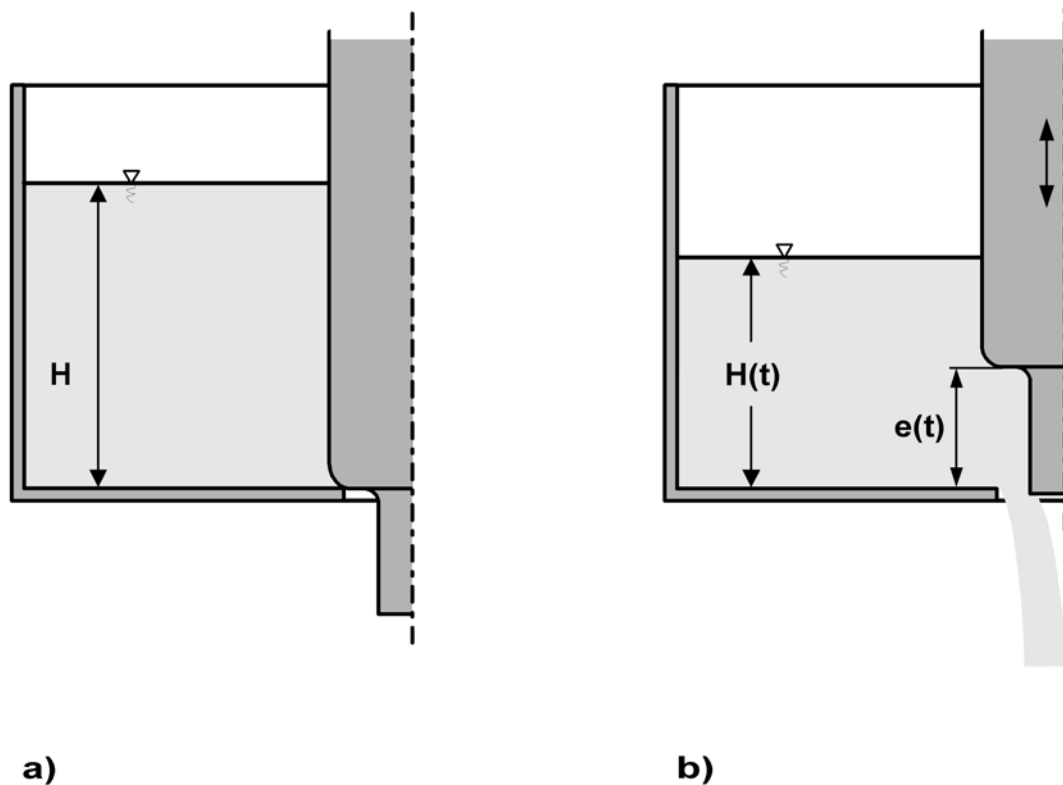


Fig. 1-1: Melt flow from ladle

Initially, the ladle is filled with melt up to a level  $H$ , and the plug is entirely closing the orifice. When pouring starts, the plug lifts up in a predefined way. Lifting up the plug gradually opens the ladle orifice in a defined way, letting the liquid metal enter the down sprue. As the plug is being lifted up, the melt flow rate of melt increases because the plug covers less and less of the ladle orifice cross section. On the other hand, as the melt flows out of the ladle, the liquid metal level in the ladle drops down, decreasing the flow rate of the metal flowing through the orifice. The above two phenomena (opening of the orifice by lifting up the plug and the lowering of the melt level in the ladle) control the flow rate of melt from the ladle.

To use the 'Plug' option, the following inputs are required:

- Definition of the plug (→ Ch. 1.4, page 10)
- Definition of the ladle (→ Ch. 1.7, page 14)
- Definition of initial melt bath height  $H$  ( $t=0$ ) (→ Ch. 1.3, page 8)

In this manual the notations shown in Fig. 1-2 are used.

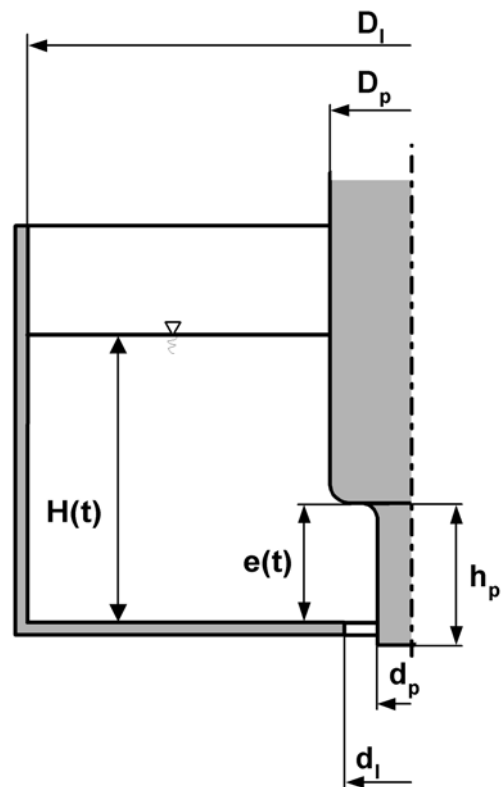


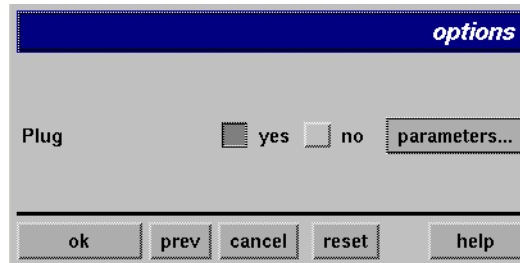
Fig. 1-2: Notations used in the 'Plug' option

## 1.2 How to Use MAGMAplug

- ⇒ Model the entire geometry of your casting system as used from standard MAGMASOFT®. For definition of the inlet geometry, see the remarks in Ch. 1.8, page 15.
- ⇒ Enmesh the geometry as usual. Note that neither the ladle nor the plug are subject to simulation; none of them is modelled or enmeshed.
- ⇒ Enter the parameters for simulation as used from standard MAGMASOFT®.

- ⇒ In the window 'options' select 'yes' to activate the option 'Plug'. Note that, depending on your license agreements, there may be more than one option in this window.

Note that only one of the options 'Plug' and 'Ladle' can be active at the same time. If both options are active an error message will appear.



*Fig. 1-3: Activating the 'Plug' option*

- ⇒ Choose 'parameters'
- ⇒ The window 'plug parameters' appears (Fig. 1-4). In this window you must define the parameters for calculating the melt flow rate based on ladle and plug characteristics.
- ⇒ Based on the geometry and the pressure loss of ladle and plug, the program automatically calculates the boundary condition for the melt flow at the inlet. Therefore you do not have to make inputs in the 'filling depends on' field in the next window 'filling definitions'; this field is disabled if the option 'Plug' is active.

### 1.3 Plug Definition

In the window 'plug parameters' you must define the ladle and plug parameters, which are needed for calculation of the melt flow rate. Each line corresponds to one plug configuration including the selected plug geometry (column 'plug'), hydraulic characteristics of the ladle/plug configuration (column 'hydraulic') and elevation of the plug (column 'elevation'). You can edit a line with the functions in the right part of the window as follows:

- ⇒ To create a new plug configuration choose 'new'.



- ⇒ To copy a complete plug configuration to a new one, mark the corresponding line and choose 'clone'.
- ⇒ To delete a complete plug configuration, mark the corresponding line and choose 'delete'.
- ⇒ To (de)activate a plug configuration, choose '(de)activate'.

**plug parameters**

ladle:

bath height:  [ mm ]

id	active	plug	hydraulic	elevation
1	YES	project / plug1	SET	SET

Buttons: new, clone, delete, deactivate, assign plug, edit hydraulic, edit elevation

ok

*Fig. 1-4: Defining the plug*

The columns of the list mean the following:

column 'id'                      Number of the plug

column 'active'                Status of the plug

Note: Only one plug may be active for simulation.

⇒ Use 'activate' / 'deactivate' to set this option.

column 'plug'                Selected plug from database

⇒ Choose 'assign plug' to select a plug from the database. For modifying the plug geometry and creating a new plug see Ch. 1.4, page 10.

- column 'hydraulic'      Pressure loss due to plug / orifice  
 ⇒ Use the button 'edit hydraulic' to define the pressure loss due to the plug. See Ch. 1.6, page 12 for further information.
- column 'elevation'      Selected elevation of the plug,  $e(t)$ .  
 ⇒ Use the button 'edit elevation' to define the elevation of the plug. See Ch. 1.5, page 11 for further information.

## 1.4 Plug Geometry Definition

In MAGMASOFT® the geometry of the plug is described by the following dimensions, which can be stored for each plug in the database MAGMAdata:

- Diameter of the plug,  $D$
- Diameter of the tip,  $d$
- Length of the tip,  $h$

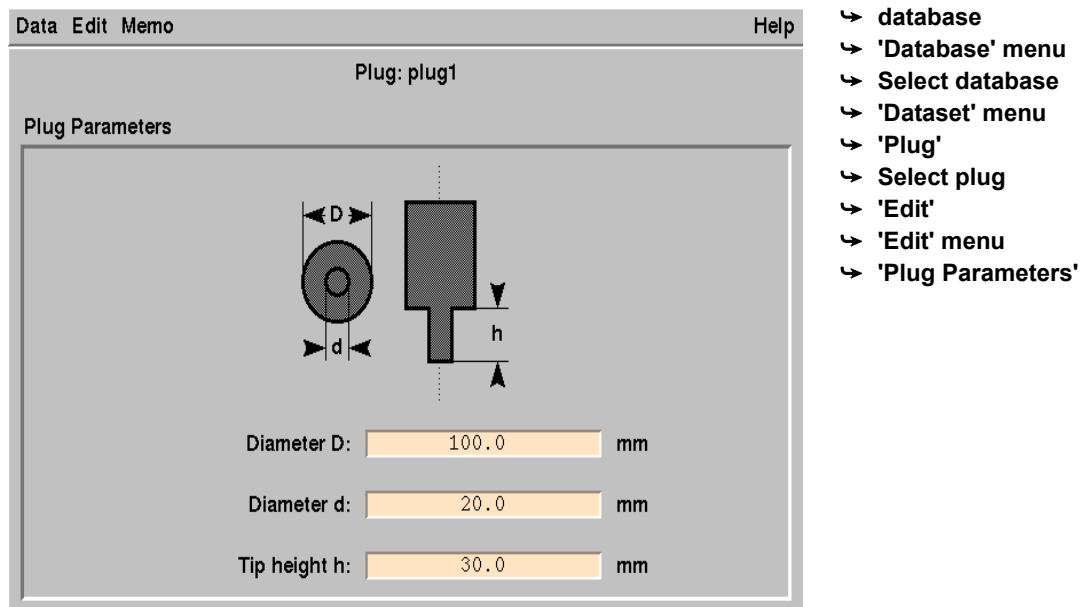


Fig. 1-5: Defining the plug geometry

⇒ Enter the geometric values of the plug. Be careful to choose geometric values corresponding to the orifice of the ladle you want to use.

! Note that you can also access datasets of the type 'Plug' via the window 'plug parameters' → 'assign plug' → 'database request'.

## 1.5 Plug Elevation Definition

The plug elevation  $e(t)$  (→ Fig. 1-1, page 5) describes the plug movement during the casting process. For example, the elevation curve shown in Fig. 1-6 corresponds to steady withdrawal of the plug with a withdrawal speed of 20 mm/s. Except for the time  $t=0$ , the plug must be at least partly open during the mold filling.

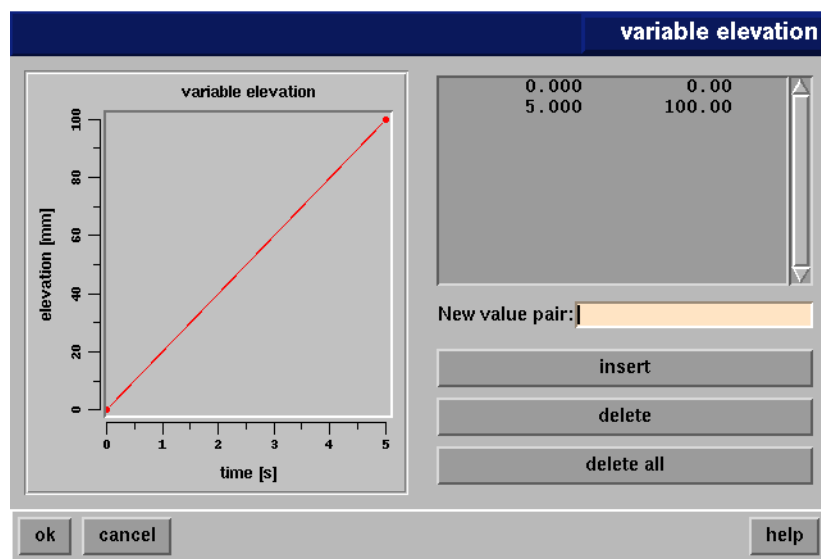


Fig. 1-6: Defining plug elevation

Proceed as follows to define the plug elevation:

⇒ In the window 'plug parameters', choose 'edit elevation'. The window 'variable elevation' appears (Fig. 1-6).

- ⇒ In the field 'New value pair', enter the value pairs (time/position) that define the plug elevation curve.
- ⇒ To insert a new value pair, mark the corresponding line just behind the one to be inserted and select 'insert'.
- ⇒ To delete a value pair, select the corresponding line and choose 'delete'
- ⇒ To delete all value pairs, choose 'delete all'.

## 1.6 Pressure Loss at Orifice / Plug

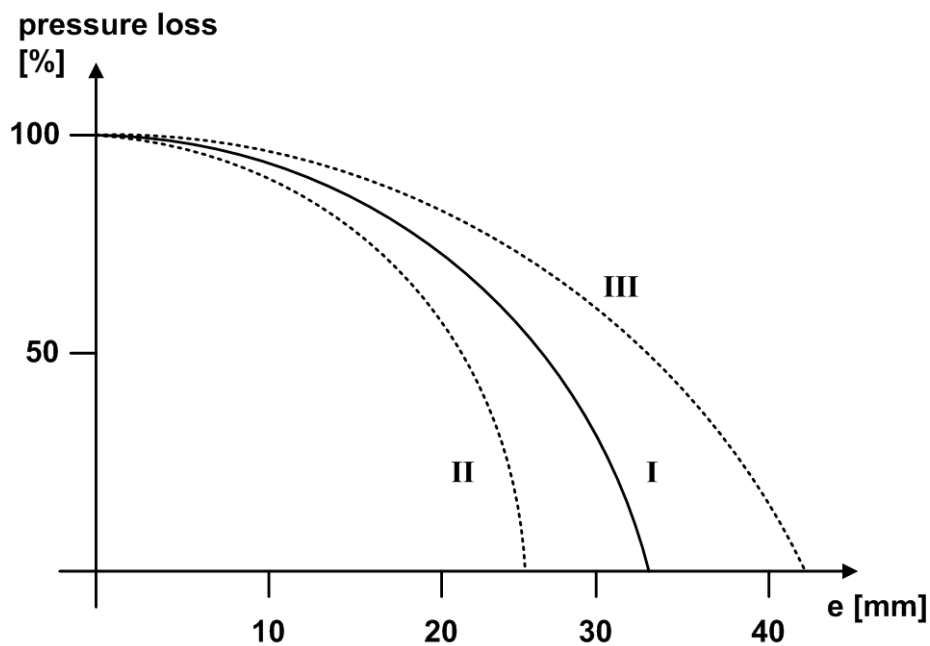


Fig. 1-7: Examples of pressure loss curves at plug / orifice

The shapes and positions of the plug and the outlet determine the pressure loss at the orifice of the ladle. Fig. 1-7 shows examples of pressure loss curves for different combinations of plug and outlet.

The horizontal axis shows plug elevation above its initial position. The vertical axis shows percent reduction of the available metallostatic pressure at the ladle orifice. When the plug is closed ( $e = 0$ ), 100% of the available pressure are lost at the outlet and no melt can flow out.

As the plug is being slowly lifted up, an increasing cross section of the orifice is open to the flow. Flow rate at the orifice increases, and hence, less pressure is lost at the orifice. The exact shape of the pressure loss curve depends on the geometry (i.e. dimensions and shapes) of the plug and orifice. For most of the typical plug/orifice geometries, the curve should look like the parabola I depicted in Fig. 1-7. You should input the pressure loss curve via the 'options' window ('plug' → 'Parameters' → 'edit hydraulic'). You can obtain the exact shape of the curve for a given ladle and plug by measuring ladle emptying times at different plug elevations.

Fig. 1-7 shows examples of pressure loss curves for different shapes of the plug. Curve II corresponds to a smaller tip diameter  $d_p < d_p^*$ , while curve III corresponds to a larger tip diameter  $d_p > d_p^*$ . The asterisk denotes the tip diameter according to pressure loss curve I.

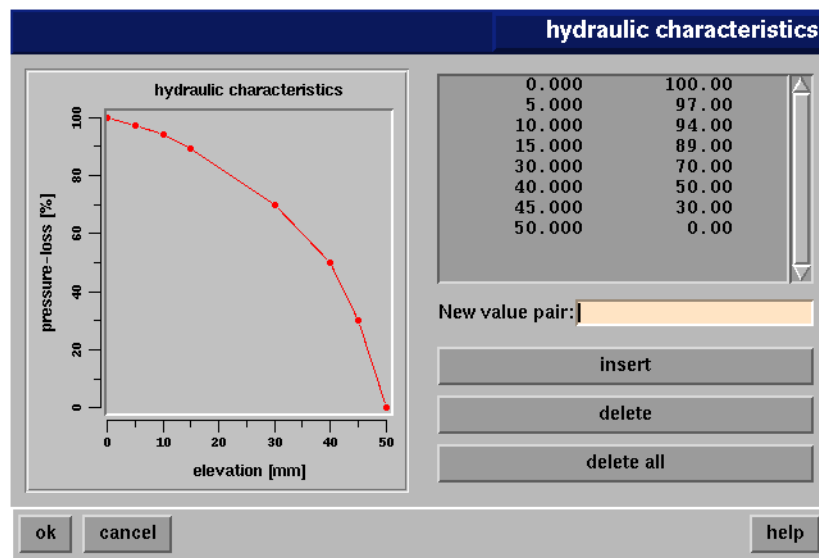


Fig. 1-8: Defining pressure loss for a plug/orifice combination

Proceed as follows to define the pressure loss of a plug/orifice combination:

- ⇒ In the window 'plug parameters', choose the 'edit hydraulic' button. The window 'hydraulic characteristics' appears (Fig. 1-8).
- ⇒ In the field 'New value pair', enter the value pairs ('elevation'/'pressure loss') defining the pressure loss depending on the plug position.
- ⇒ To insert a new value pair, mark the corresponding line just behind the one to be inserted and select 'insert'.
- ⇒ To delete a value pair, select the corresponding line and choose 'delete'
- ⇒ To delete all value pairs, choose 'delete all'.

## 1.7 Ladle Geometry

The ladle geometry is characterized by the parameters shown in the 'Ladle Parameters' window (Fig. 1-9). Please note that the 'Plug' option supports only cylindrical ladles (Taper = 90°). Modify the  $D_L$  value if the shape of your ladle has a different angle of inclination.

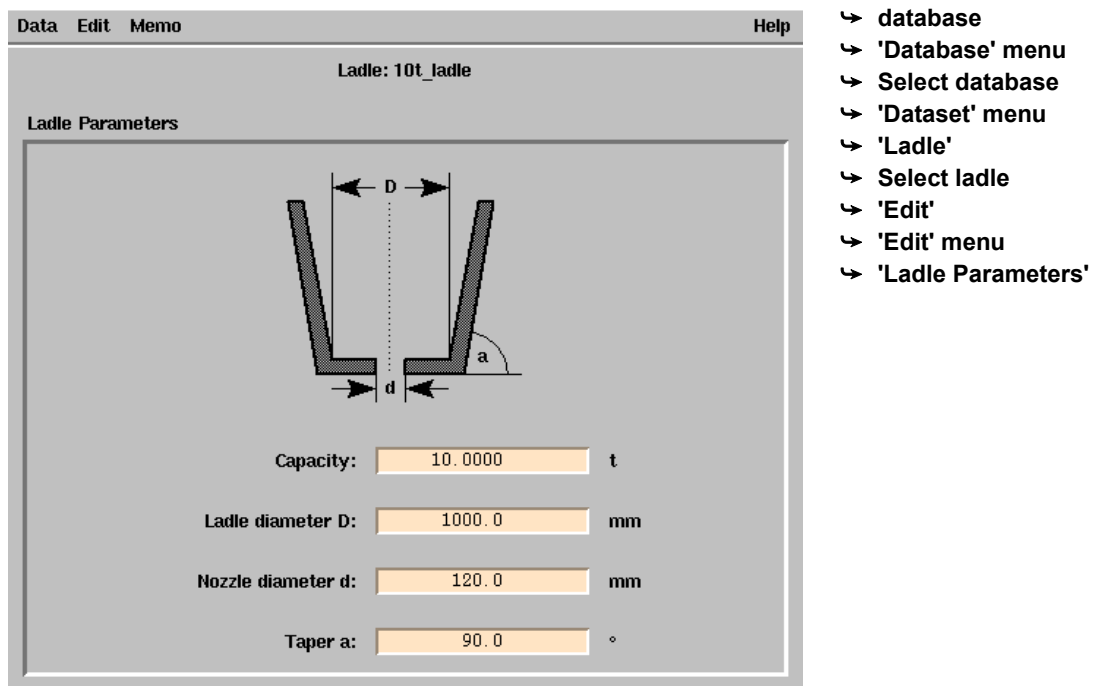


Fig. 1-9: Defining ladle geometry

⇒ Enter the parameters in the corresponding fields.

- ! Note that you can also access datasets of the type 'Ladle' via the window 'plug parameters' → 'ladle' → 'database request'.

## 1.8 Defining the Cross Section of the Melt Stream

During geometry modeling, you should define the volume assigned to the material group 'Inlet' at the top end of the down sprue. The diameter of the inlet should include the reduction of the melt stream diameter between the ladle orifice and the inlet entry:

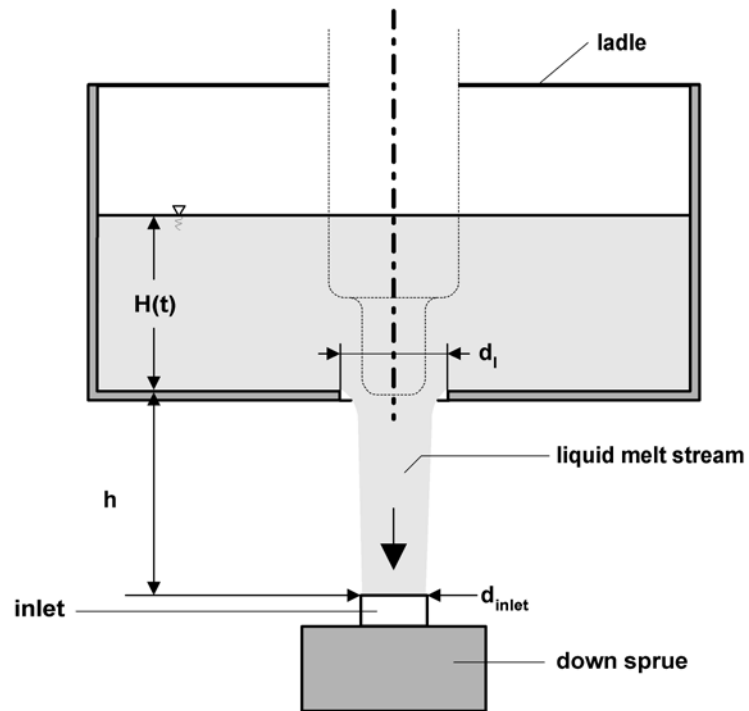


Fig. 1-10: Defining inlet cross section

You can estimate the reduced cross section of the melt flow using the following equation:

$$A_{inlet} = \text{MIN} \left( 0.8, \sqrt{\frac{H_{avg}}{H_{avg} + h}} \right) \cdot A_L \quad \text{Equation 1-1}$$

$A_{inlet}$	Cross section of the inlet
$H_{avg}$	Average bath height during pouring of the part
$h$	Distance between inlet and ladle orifice
$A_L$	Ladle orifice cross section



In Equation 1-1, MIN denotes the minimum value of the arguments written in paranthesis.  $H_{avg}$  denotes the average bath height during pouring of the casting (e.g.  $H_{avg} = 0.5H$  when the entire ladle content is poured for one casting).

Please refer also to Ch. 3.12, page 3-117 of the MAGMASOFT® 4.4 Manual, where you find detailed information on how to determine the inlet size.

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## Notes

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