



3rd International Conference
16–19 October 2018 in Stockholm

Optimization of ingot geometry, casting technology and chemical composition of a 20 tons 42CrMo4 ingot to minimize A-segregation and increase material homogeneity

**Ovidiu Bogdan, Industrial Soft
Montreal, Canada**

Outline

A Segregation in Steel Ingots

Analysis Tools

- Online Ingot and Mold Design
- Online Solidification Simulation and Segregation Analysis
- Segregation Prediction Technique

Optimization of Ingot Geometry

- H/D ratio, Ingot Taper, Hot Top Size

Optimization of Casting technology

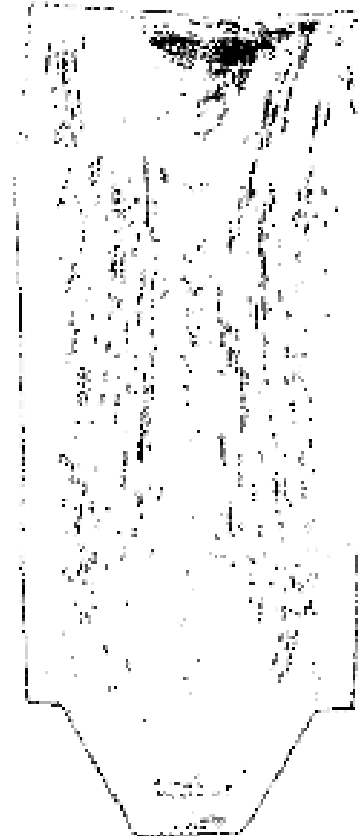
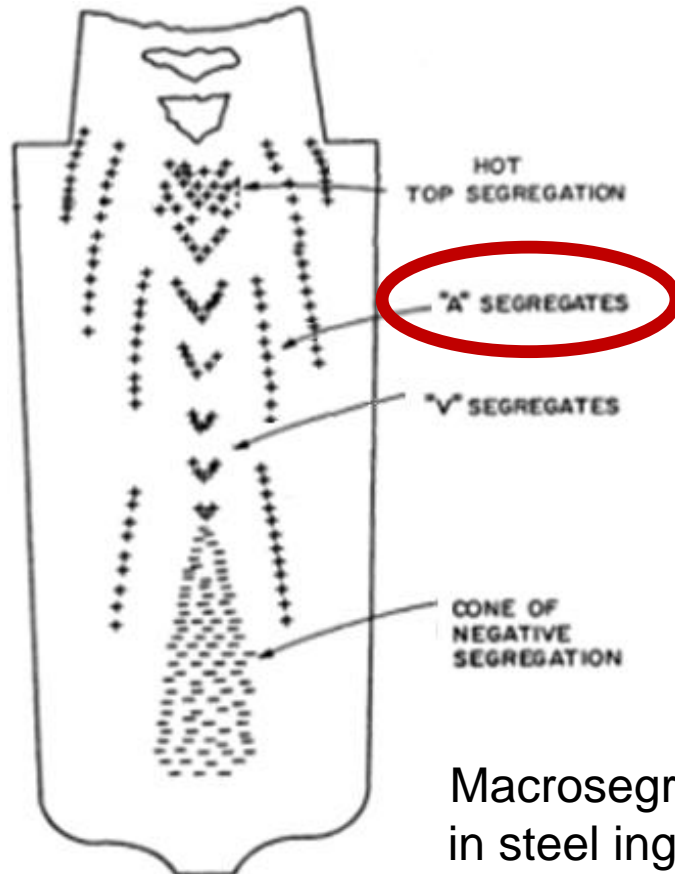
- Pouring Temperature, Exothermic Material

Optimization of Chemical Composition

- C, Si, Mn, Cr, Mo

Conclusions

Macrosegregation in Steel Ingots



Sulfur print in sectioned ingots

Online Ingot and Mold Design Assistant

The screenshot shows a web browser window displaying the SIMCADE.COM website. The browser's address bar shows the URL <http://52.60.199.37/>. The website's navigation menu includes links for **SIMCADE.COM**, **Mold Projects**, **Segregation Analysis Projects**, **Edit Databases**, **Contact us**, and **LOGOUT**. The main header features the text **SIMCADE.COM - INDUSTRIAL SOFT** and a sub-header: **Online Ingot Mold Design Solidification Simulation and Online Segregation Analysis**.

The page is divided into several sections:

- NAVIGATION:** A vertical list of links including HOME, INGOT MOLD DESIGN, SEGREGATION ANALYSIS, MOLD DESIGN, VIDEOS - PUBLICATIONS, ABOUT, and CONTACT.
- HIGHLIGHTS:** A section with an orange header containing a "Home" link and a news item dated **Feb, 2018** from the Swedish Steel Producers Association regarding the 3rd INGOT CASTING, ROLLING conference.
- Products and Services:** A central section with a blue header and two columns of services:
 - Online Ingot Mold Design:** Accompanied by a checkmark icon, with text stating "Many reports published in the last several years show clearly".
 - Solidification and Segregation Analysis:** Also accompanied by a checkmark icon, with text stating "By the simulation service and A-segregations we check if the".
- GET NEWS:** A section with an orange header, a text input field, and a "Subscribe" button.
- CONTACT INFO:** A section with an orange header, a world map image, and contact details for **Industrial Soft** in Montreal, including the email webmaste@castingsnet.com.

The browser's status bar at the bottom shows the time as 2:08 PM and the system tray with various application icons.

Online Ingot and Mold Design Assistant

The screenshot shows a web browser window displaying the SIMCADE.COM website. The browser title is "Ingot Solidification Simulation - A Segregation Prediction - K-Meleon". The address bar shows "http://52.60.199.37/". The website has a dark blue header with the SIMCADE.COM logo and navigation links: "Mold Projects", "Segregation Analysis Projects", "Edit Databases", "Contact us", and "LOGOUT".

The main content area features a large blue banner with the text "SIMCADE.COM - INDUSTRIAL SOFT" and "Online Ingot Mold Design Solidification Simulation and Online Segregation Analysis".

On the left side, there is a "NAVIGATION" menu with links to HOME, INGOT MOLD DESIGN, SEGREGATION ANALYSIS, MOLD DESIGN, VIDEOS - PUBLICATIONS, ABOUT, and CONTACT. Below this is a "HIGHLIGHTS" section with a "Home" link and a news item dated "Feb, 2018" about the Swedish Steel Producers Association conference.

The central "Products and Services" section includes a globe icon and text: "Industrial Sof is a software development and web design company. We are located in Montreal, Canada, but we can serve you wherever you are in the world." It also states: "Industrial Soft creates custom software applications that are designed specifically to fit your company. At the moment we offer the following products and services".

Two product/service boxes are shown: "Online Ingot Mold Design" with a checkmark icon and the text "Many reports published in the last several years show clearly", and "Solification and Segregation Analysis" with a checkmark icon and the text "By the simulation service and A-segregations we check if the".

On the right side, there is a "GET NEWS" section with a search box and a "Subscribe" button, and a "CONTACT INFO" section with a world map icon, the address "Industrial Soft Montreal, Qc H3P 2C7", and the email "webmaste@castingsnet.com".

The browser's taskbar at the bottom shows several open tabs and the system tray with the time "2:08 PM".

Online Solidification and A Segregation Analysis

The screenshot displays the SIMCADE.COM website interface. At the top, the browser title is "Ingot Solidification Simulation - A Segregation Prediction - K-Meleon". The address bar shows "http://52.60.199.37/". The website header includes navigation links: "SIMCADE.COM", "Mold Projects", "Segregation Analysis", "Databases", "Contact us", "Reports", and "LOGOUT". The main banner reads "SIMCADE.COM - INDUSTRIAL SOFT" with the tagline "Online Ingot Mold Design Solidification Simulation and Online Segregation Analysis".

The left sidebar contains a "NAVIGATION" menu with links to HOME, INGOT MOLD DESIGN, SEGREGATION ANALYSIS, MOLD DESIGN, VIDEOS - PUBLICATIONS, ABOUT, and CONTACT. Below it is a "HIGHLIGHTS" section featuring a "Home" link and a news item from "Feb, 2018" about the Swedish Steel Producers Association's announcement for the 3rd INGOT CASTING, ROLLING and FORGING CONFERENCE, ICRF 2018, with a "Read more..." link.

The main content area is titled "Products and Services" and describes Industrial Sof as a software development and web design company. It lists two services: "Online Ingot Mold Design" and "Solidification and Segregation Analysis". The "Solidification and Segregation Analysis" section explains that the simulation service checks if the ingot size, shape, and chemical composition allow for a forging product free of segregation and homogeneous mechanical properties. It also mentions that the A-segregations prediction module is based on the mechanism proposed by K.Suzuki and T.Miyamoto from Japan Steel Works Ltd.

On the right side, there is a "GET NEWS" section with a "Subscribe" button and a "CONTACT INFO" section with a world map icon, contact details for Industrial Soft (Montreal, Qc H3P 2C7), email (webmaste@castingsnet.com), and phone number (514) 342-5833.

The bottom of the browser window shows the Windows taskbar with the time 7:32 AM and the system tray.

Online Solidification and A Segregation Analysis



The screenshot shows a web browser window displaying the SIMCADE.COM website. The browser title is "Ingot Solidification Simulation - A Segregation Prediction - K-Meleon". The address bar shows "http://52.60.199.37/". The website has a navigation menu with links for "Mold Projects", "Segregation Analysis", "Databases", "Contact us", "Reports", and "LOGOUT". The main heading is "SIMCADE.COM - INDUSTRIAL SOFT". Below this, it says "Online Ingot Mold Design" and "Solidification Simulation and Online Segregation Analysis".

NAVIGATION

- HOME
- INGOT MOLD DESIGN
- SEGREGATION ANALYSIS
- MOLD DESIGN
- VIDEOS - PUBLICATIONS
- ABOUT
- CONTACT

HIGHLIGHTS

- Home
- Feb, 2018**
The Swedish Steel Producers Association, is pleased to announce the international conference: 3rd INGOT CASTING, ROLLING and FORGING CONFERENCE, ICRF 2018 [Read more...](#)

Products and Services

Industrial Sof is a software development and web design company. We are located in Montreal, Canada, but we can serve you wherever you are in the world.

Industrial Soft creates custom software applications that are designed specifically to fit your company. At the moment we offer the following products and services

Online Ingot Mold Design

Many reports published in the last several years show clearly that we can not have an ingot free of segregation without choosing its size and geometry according to the forging shape and the chemical composition of the steel.

Having in view these premises, simcade.com - Industrial Soft, has been focused on developing of an integrated online ingot design tool to allow engineers to reduce substantially the time they need to increase the internal

Solidification and Segregation Analysis

By the simulation service and A-segregations we check if the ingot size, shape and the chemical composition of your steel allows you to have a forging product free of segregation and homogeneous mechanical properties.

A-segregations prediction module, based on the mechanism proposed by K.Suzuki and T.Miyamoto from Japan Steel Works Ltd. and developed by Industrial Soft is employed with solidification software SimCADE v.2.0 in this

GET NEWS

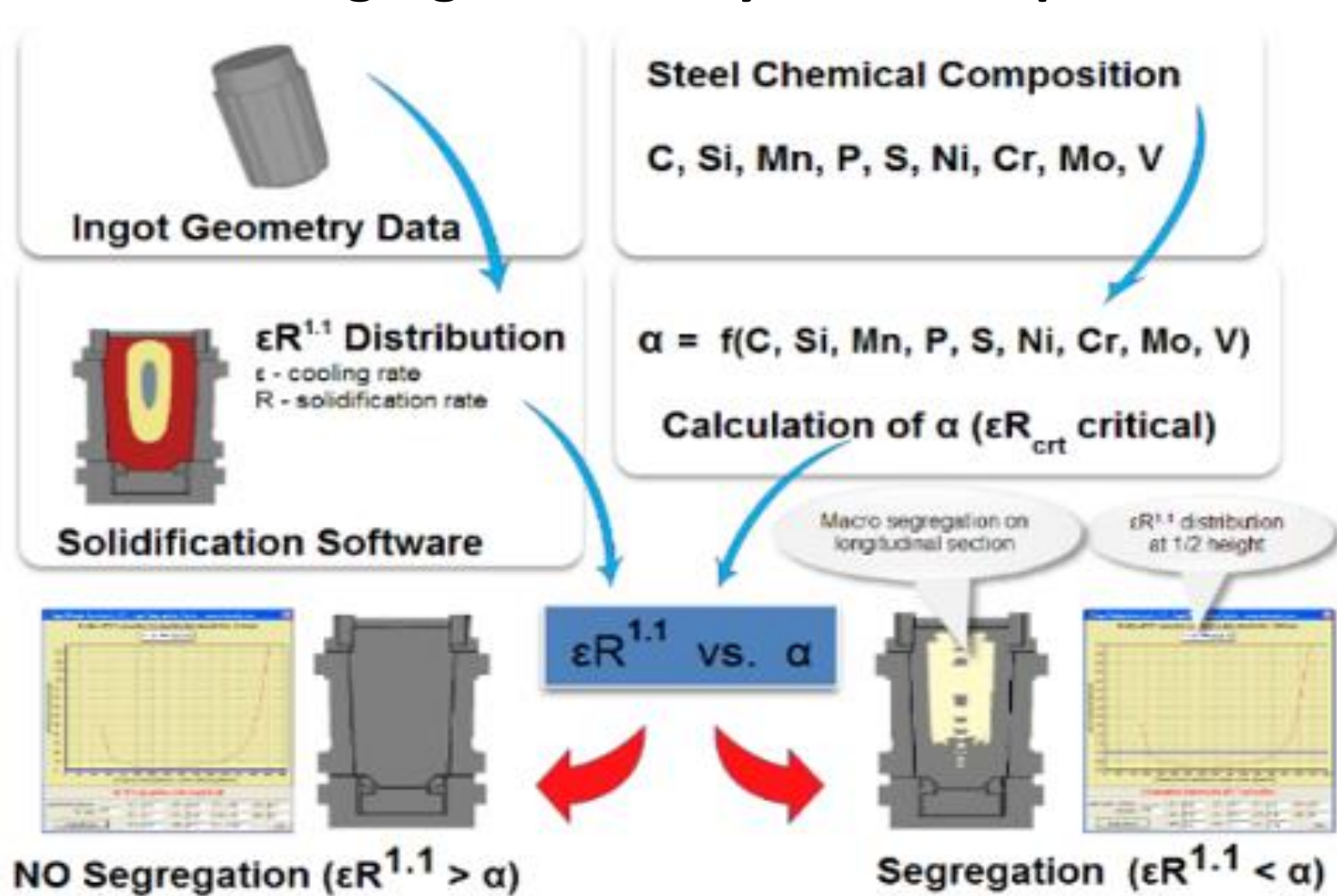
CONTACT INFO



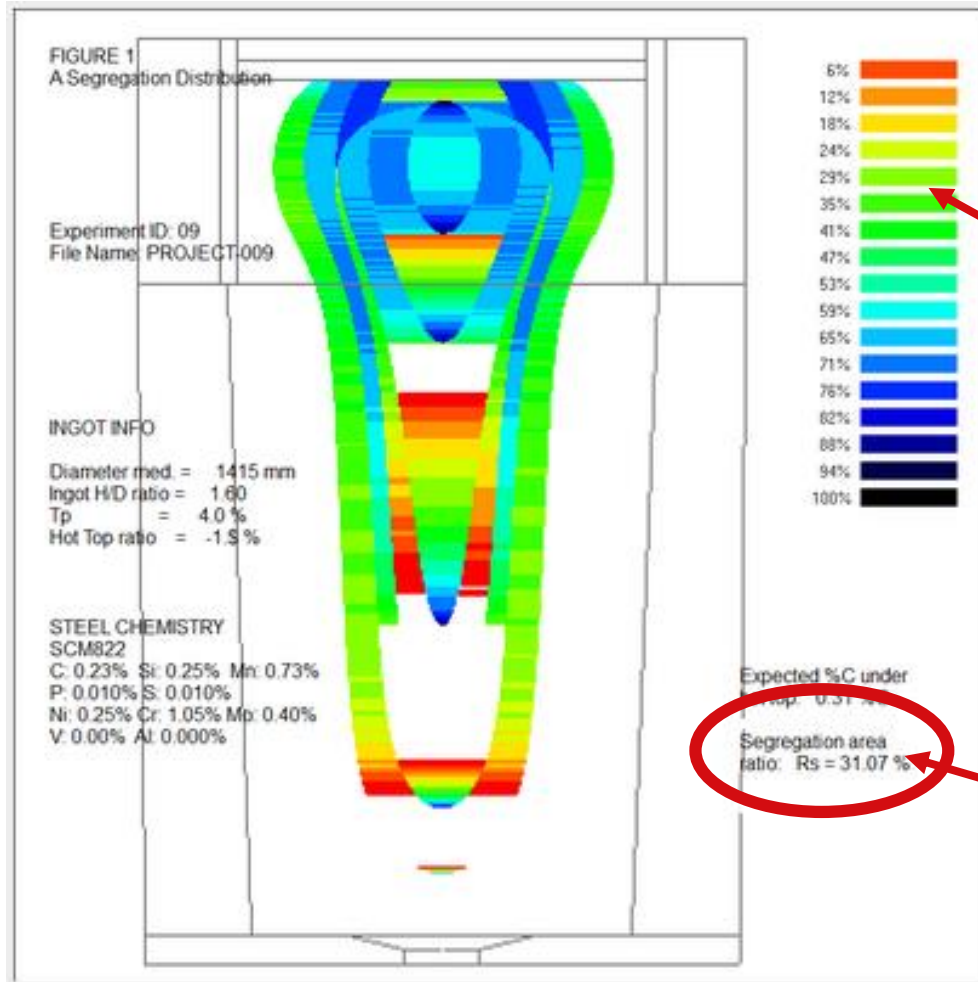
Industrial Soft
Montreal, Qc H3P 2C7
Email: webmaste@castingsnet.com
Phone: (514) 342-5833

The browser taskbar at the bottom shows the Windows taskbar with various application icons and the system tray displaying the time as 7:32 AM.

A Segregation Analysis Technique

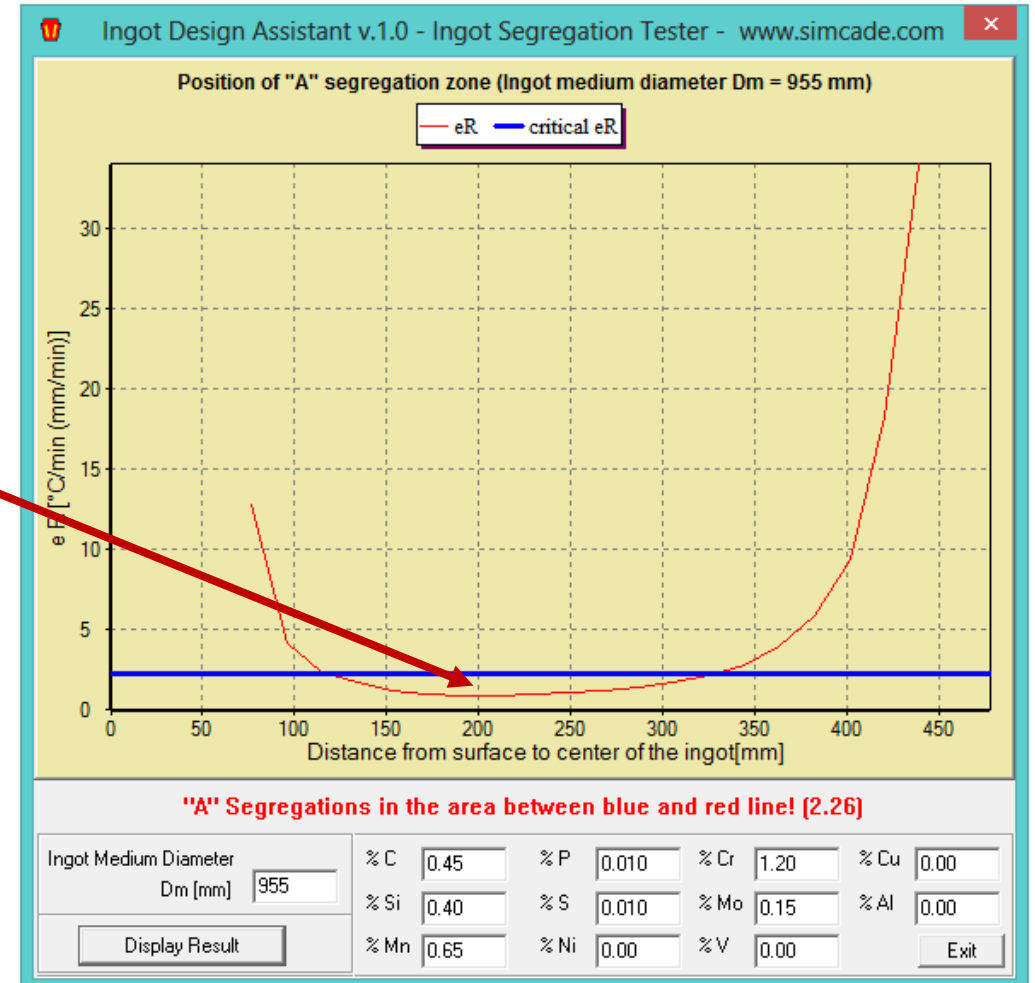


A Segregation Assessment Indicators



Segregation
intensity

Segregation
area ratio



Optimization of Ingot Geometry



a. H/D: 3.0



b. H/D: 4.0



c. H/D: 5.0

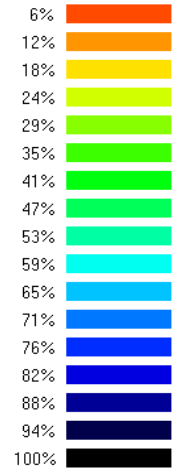
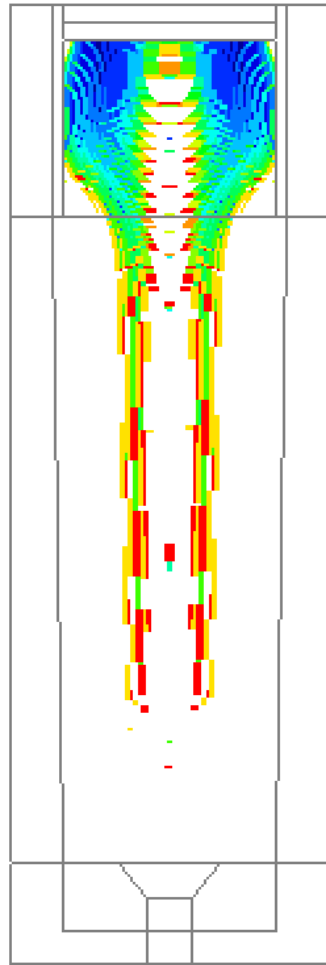
	<i>C</i>	<i>Si</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Cr</i>	<i>Mo</i>
42CrMo4	0.41	0.30	0.70	0.01	0.01	0.80	0.20

Table 1. Chemical composition of analyzed steel

Ingot ID	Ingot Weight	Body Weight	Hot Top	Ingot H/D
a	20T	16T	20.0%	3.0
b	20T	16T	20.0%	4.0
c	20T	16T	20.0%	5.0

Table 2. Size of the ingots analyzed

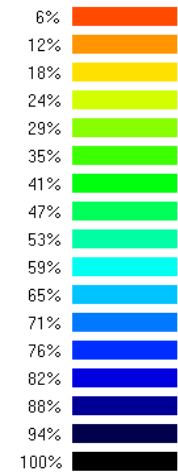
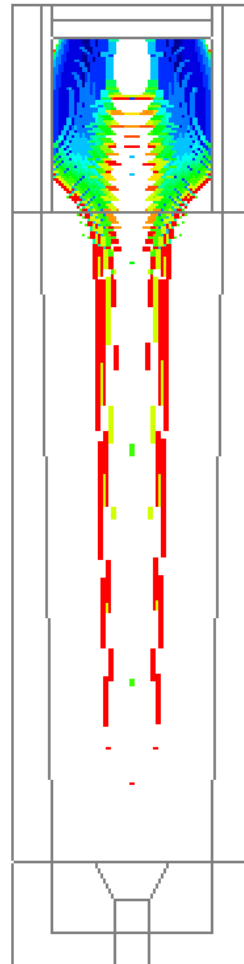
A Segregation function by H/D ingot ratio



Expected %C under hot top: 0.54 %C

Segregation area ratio: $R_s = 15.78\%$

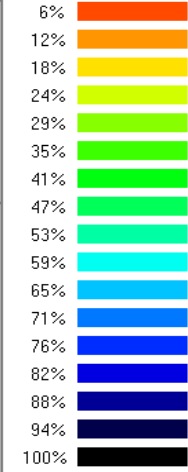
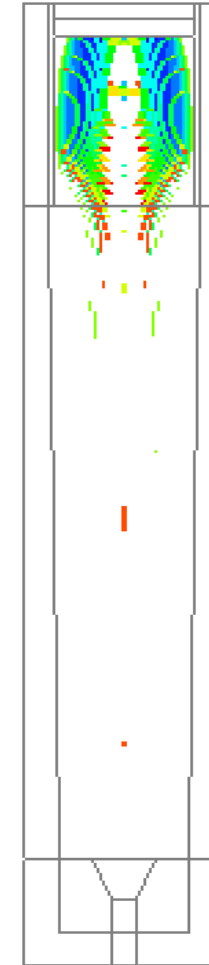
H/D: 3.0



Expected %C under hot top: 0.54 %C

Segregation area ratio: $R_s = 10.90\%$

H/D: 4.0

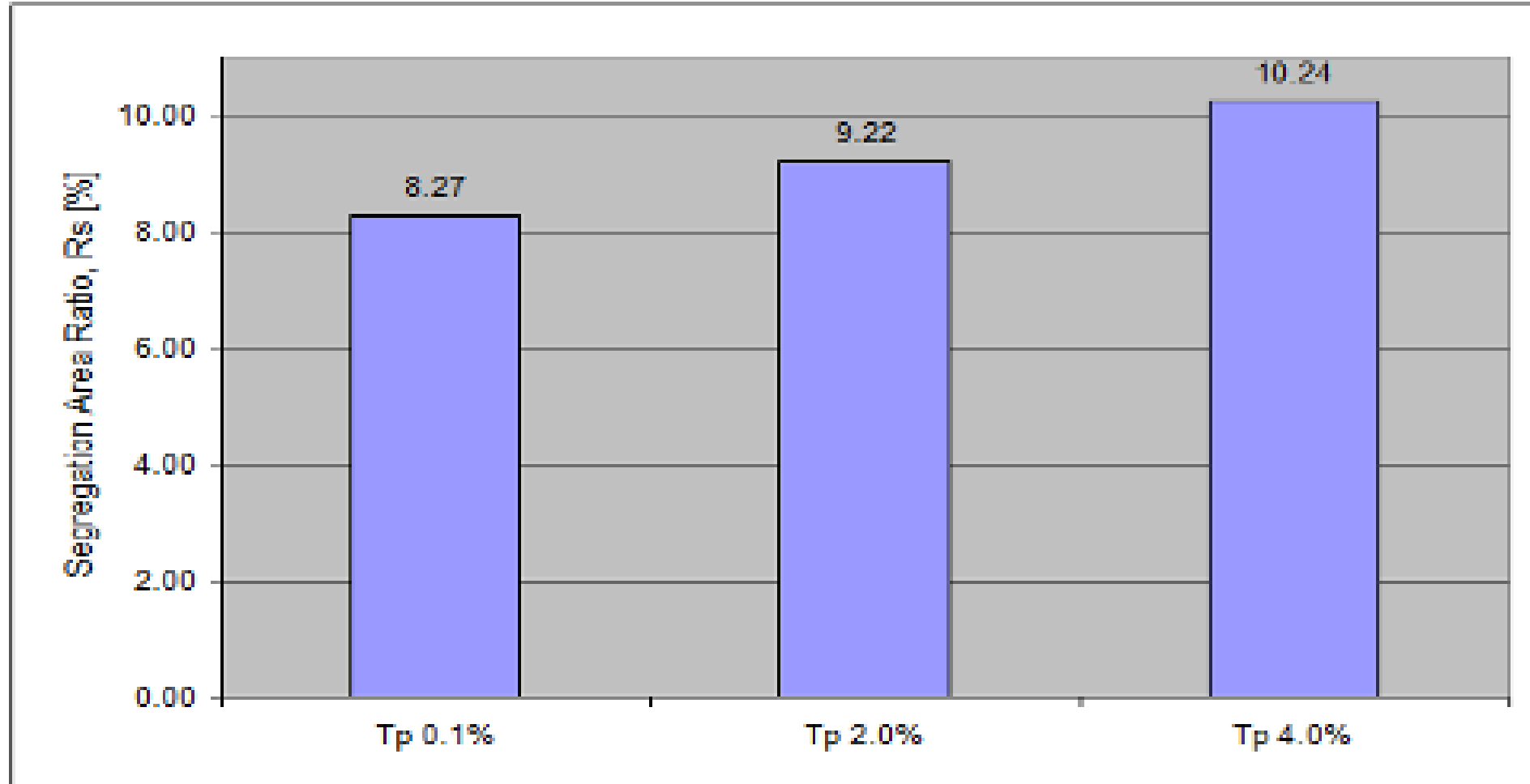


Expected %C under hot top: 0.55 %C

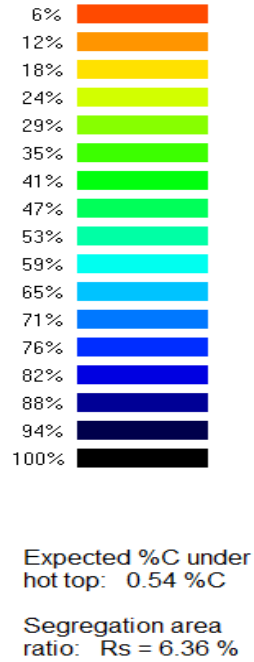
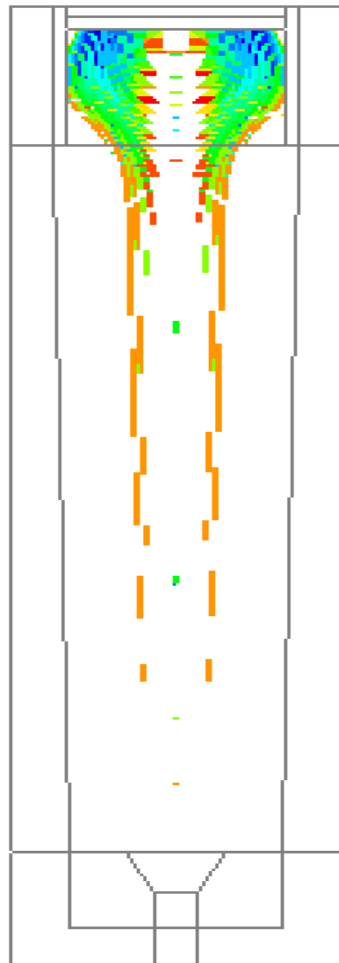
Segregation area ratio: $R_s = 1.58\%$

H/D: 5.0

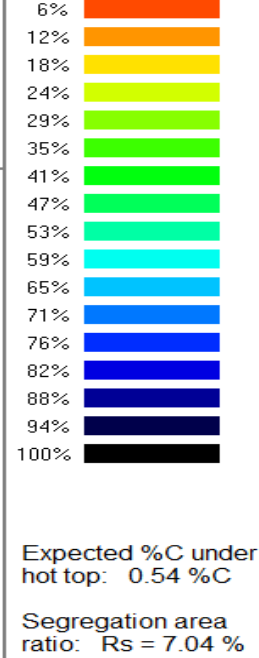
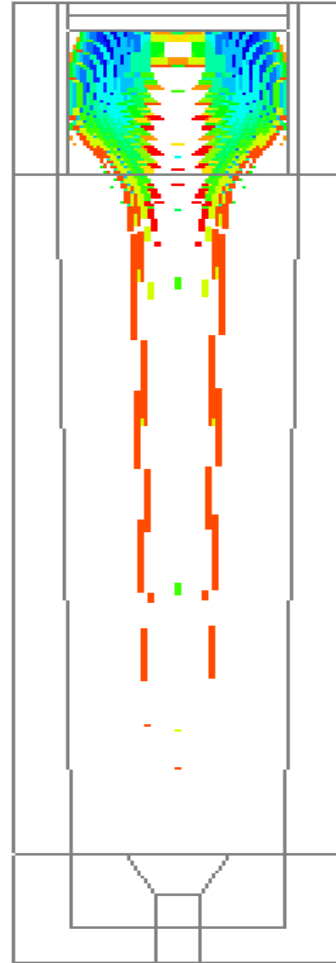
A Segregation function by Ingot Taper



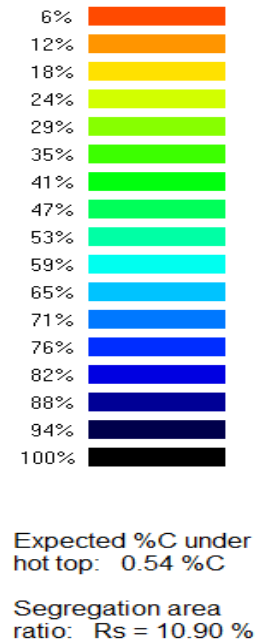
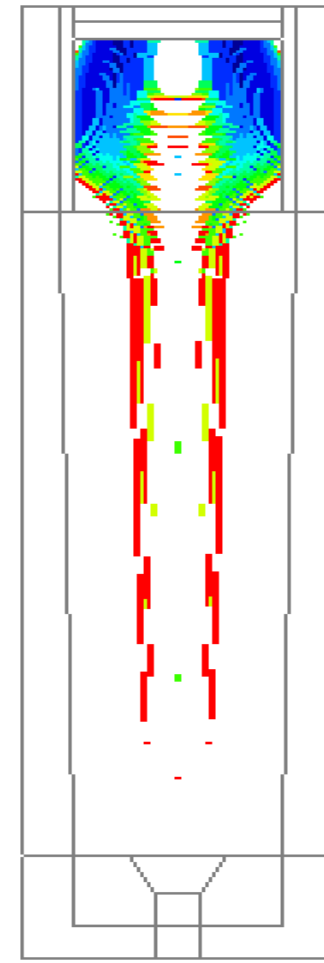
A Segregation function by Hot Top Size



Hot top 13.5%

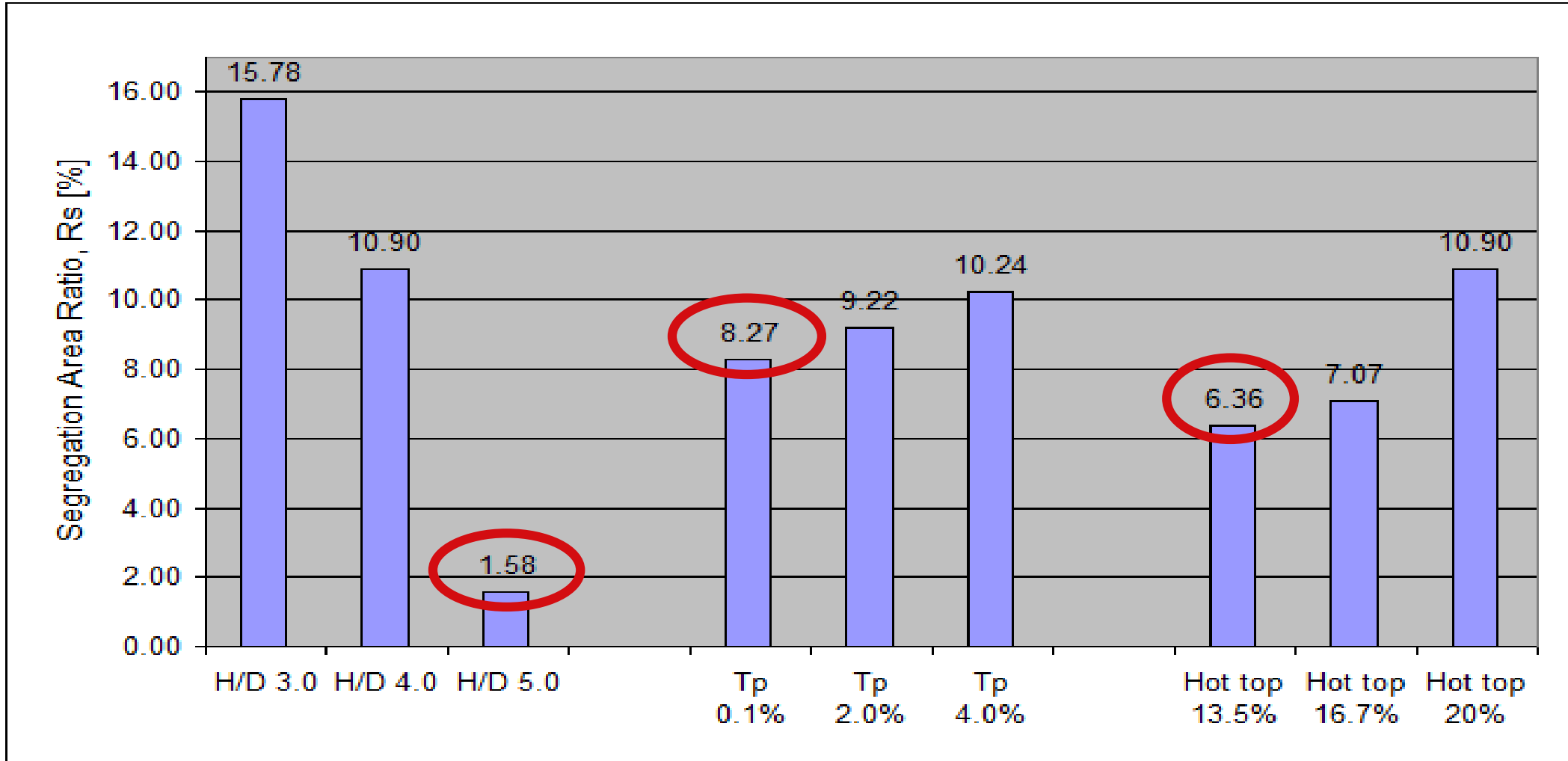


Hot top 16.7%

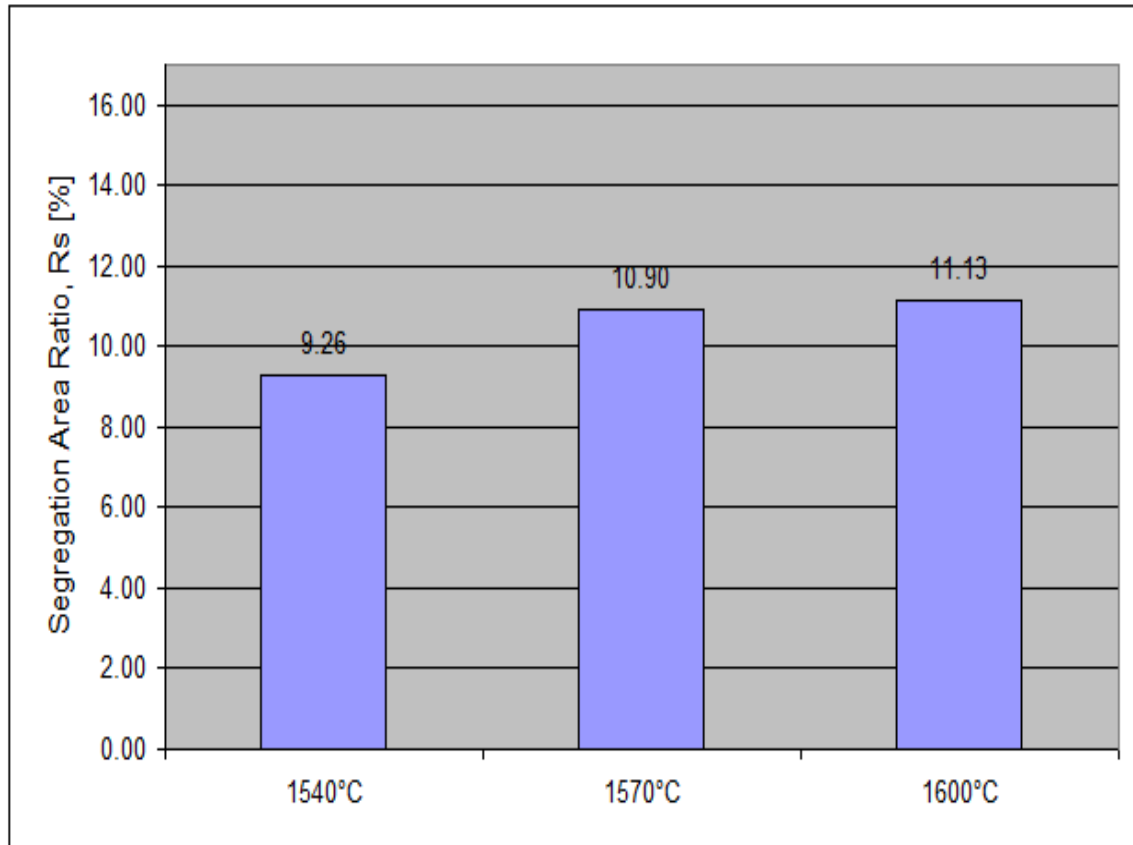


Hot top 20.0%

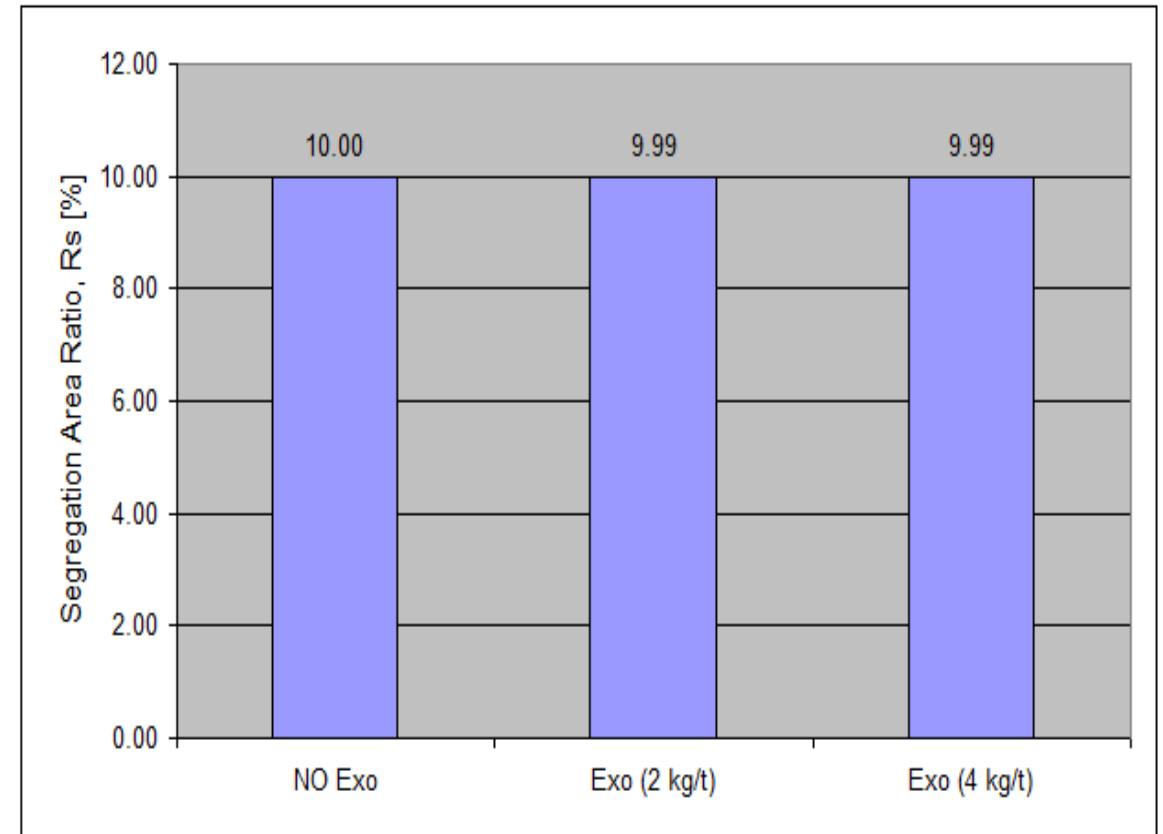
Choosing the ingot geometry to minimize A segregation



A Segregation function by Pouring Temperature and Exothermic Material



A Segregation area function by pouring temperature

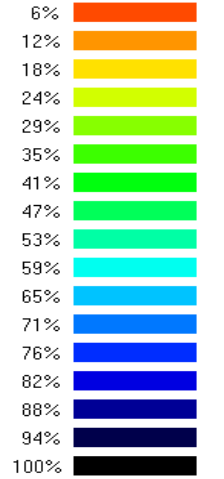
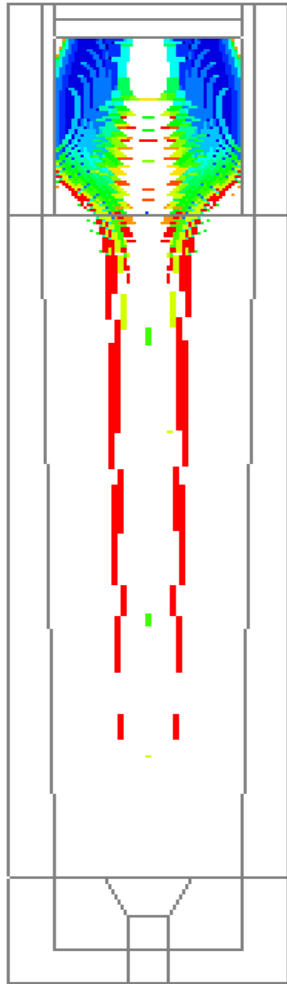


A Segregation area function by exothermic material 15

Optimization of chemical composition

	C	Si	Mn	Cr	Mo
Reference	0.41	0.30	0.70	1.05	0.20
Carbon	0.38	0.30	0.70	1.05	0.20
Carbon	0.45	0.30	0.70	1.05	0.20
Silicon	0.41	0.15	0.70	1.05	0.20
Silicon	0.41	0.40	0.70	1.05	0.20
Manganese	0.41	0.30	0.65	1.05	0.20
Manganese	0.41	0.30	0.90	1.05	0.20
Chromium	0.41	0.30	0.70	0.90	0.20
Chromium	0.41	0.30	0.70	1.20	0.20
Molybdenum	0.41	0.30	0.70	1.05	0.15
Molybdenum	0.41	0.30	0.70	1.05	0.30

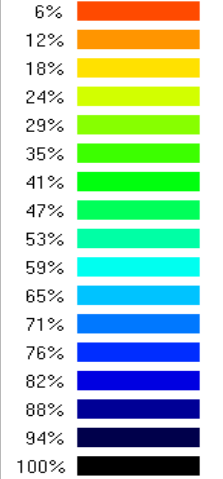
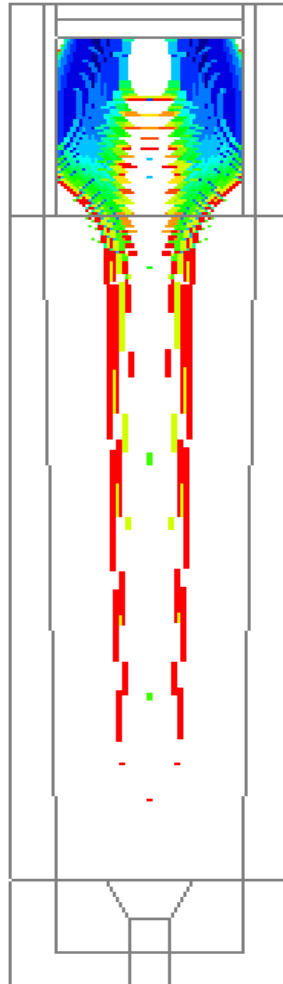
A Segregation function by Carbon content



Expected %C under hot top: 0.50 %C

Segregation area ratio: $R_s = 8.21\%$

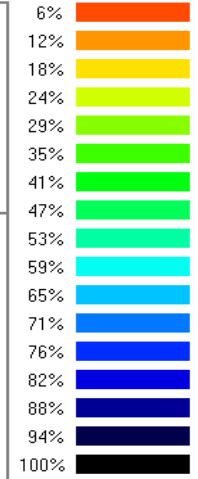
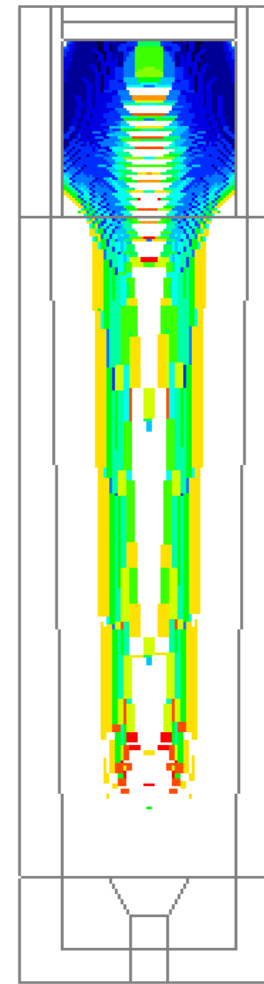
Carbon: 0.38%



Expected %C under hot top: 0.54 %C

Segregation area ratio: $R_s = 10.90\%$

Carbon: 0.41%

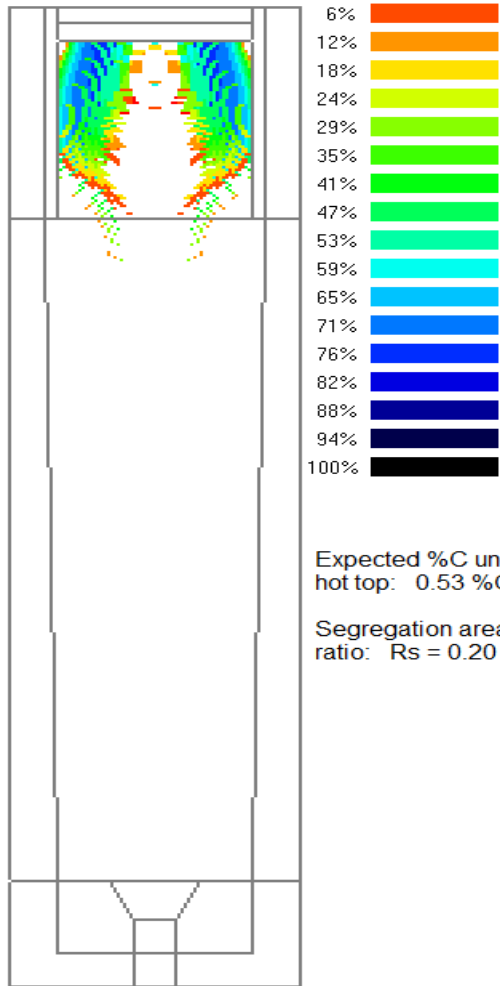


Expected %C under hot top: 0.60 %C

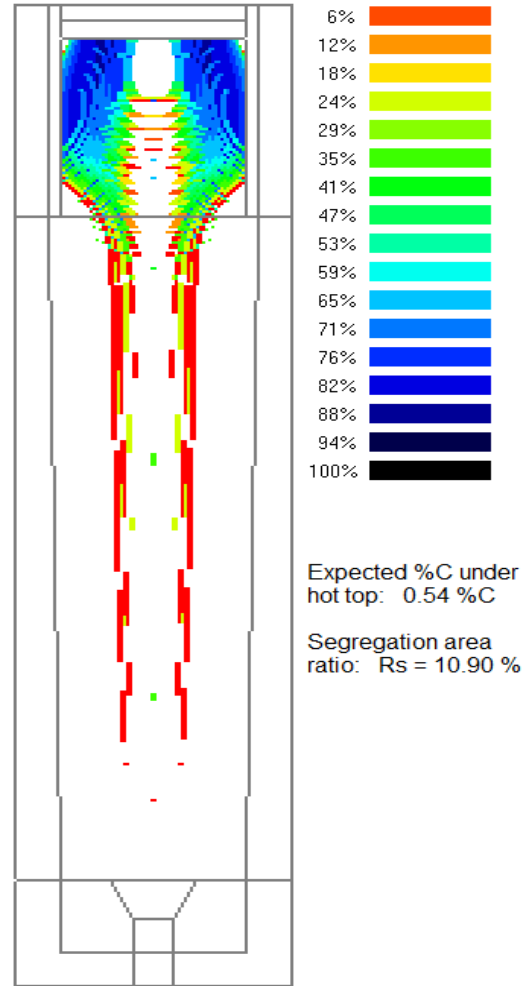
Segregation area ratio: $R_s = 35.28\%$

Carbon: 0.45%

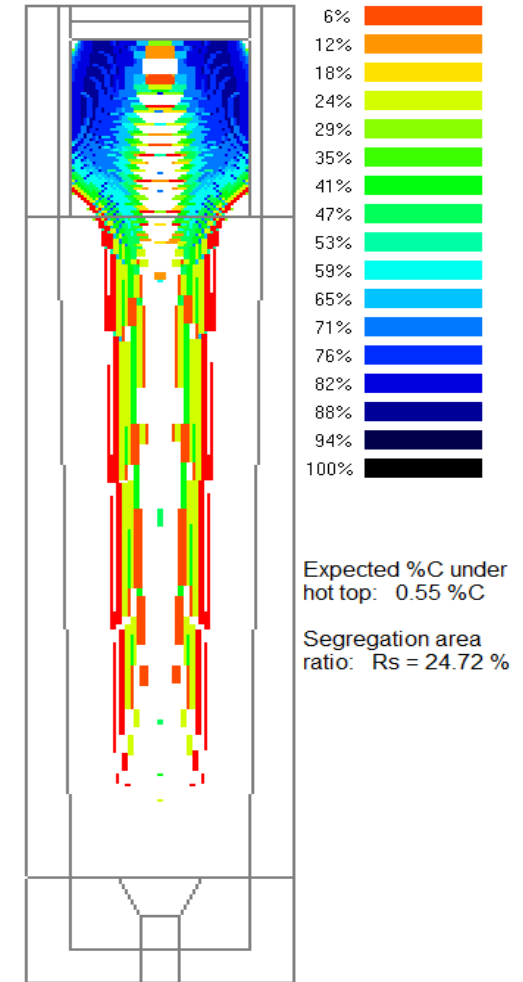
A Segregation function by Silicon content



Silicon: 0.15%

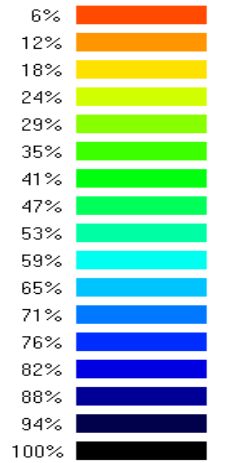
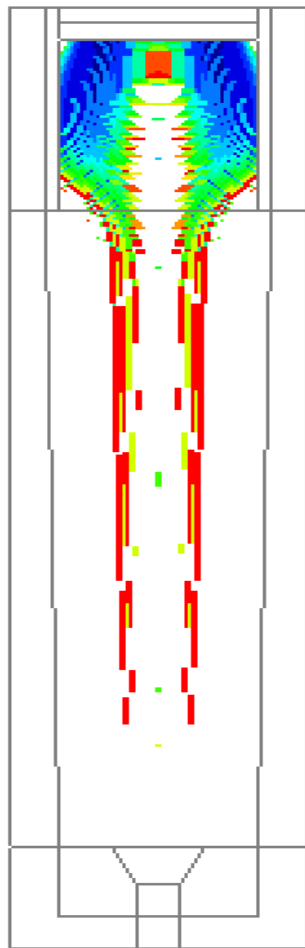


Silicon: 0.30%



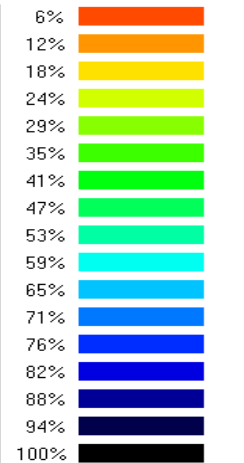
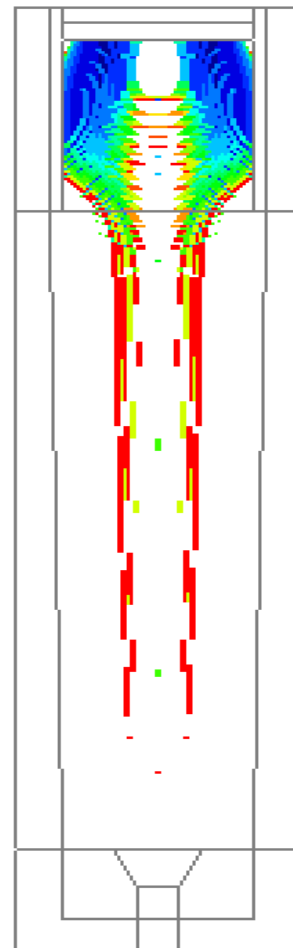
Silicon: 0.40%

A Segregation function by Molybdenum content



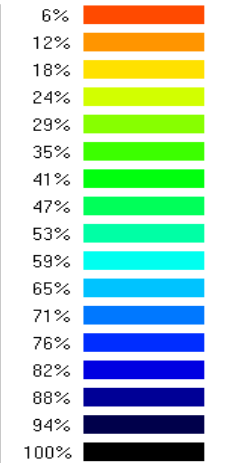
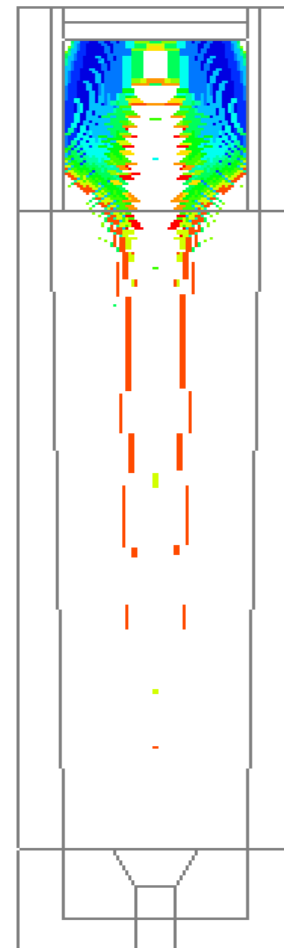
Expected %C under hot top: 0.54 %C

Segregation area ratio: $R_s = 12.19\%$



Expected %C under hot top: 0.54 %C

Segregation area ratio: $R_s = 10.90\%$



Expected %C under hot top: 0.54 %C

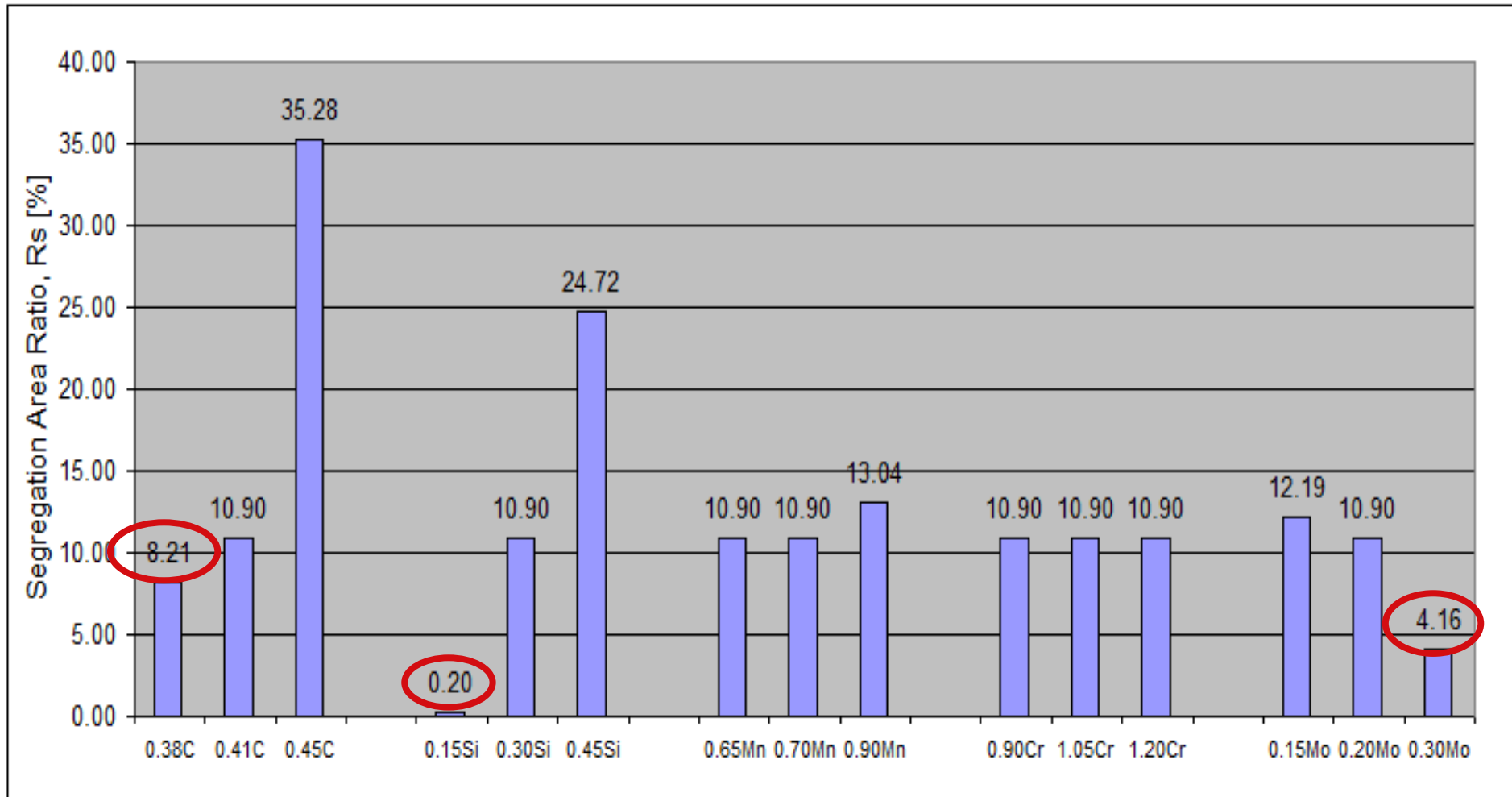
Segregation area ratio: $R_s = 4.16\%$

Molybdenum: 0.15%

Molybdenum: 0.20%

Molybdenum: 0.30%

A Segregation function by Chemical Element



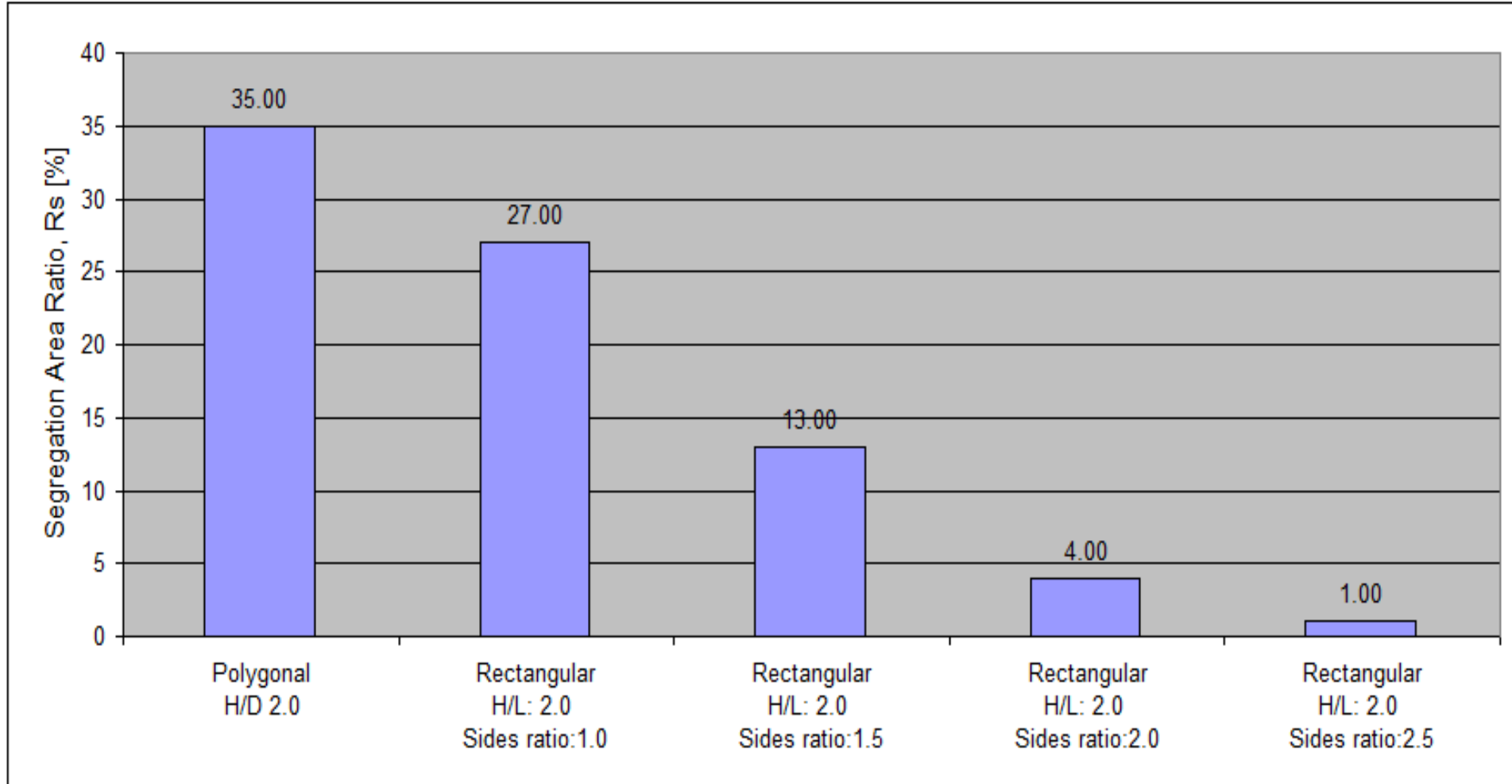
Ingots for Forged Plates

The screenshot displays the SIMCADE.COM website interface. At the top, there is a navigation menu with links for 'Mold Projects', 'Segregation Analysis', 'Databases', 'Contact us', 'Reports', and 'LOGOUT'. The main header features the text 'SIMCADE.COM - INDUSTRIAL SOFT' and 'Online Ingot Mold Design Solidification Simulation and Online Segregation Analysis'. A left sidebar contains a 'NAVIGATION' menu with links to 'HOME', 'INGOT MOLD DESIGN', 'SEGREGATION ANALYSIS', 'MOLD DESIGN', 'VIDEOS - PUBLICATIONS', 'ABOUT', and 'CONTACT'. Below this is a 'HIGHLIGHTS' section with a 'Home' link and a news item dated 'Feb, 2018' regarding the 3rd INGOT CASTING, ROLLING and FORGING CONFERENCE, ICRF 2018. The main content area is titled 'Products and Services' and includes two columns: 'Online Ingot Mold Design' and 'Solidification and Segregation Analysis'. The 'Online Ingot Mold Design' section features a checkmark icon and text stating that many reports published in the last several years show clearly that ingots can be designed free of segregation. The 'Solidification and Segregation Analysis' section also features a checkmark icon and text explaining that the simulation service checks for segregation based on ingot size, shape, and chemical composition. A right sidebar contains a 'GET NEWS' section with a 'Subscribe' button and a 'CONTACT INFO' section with a world map icon, the company name 'Industrial Soft', address 'Montreal, Qc H3P 2C7', email 'webmaste@castingsnet.com', and phone number '(514) 342-5833'. The browser's address bar shows 'http://52.60.199.37/' and the taskbar at the bottom indicates the system time as 7:32 AM.

Ingots for Forged Plates

The screenshot shows a web browser window displaying the SIMCADE.COM website. The browser's address bar shows the URL <http://52.60.199.37/>. The website has a navigation menu with links for 'Mold Projects', 'Segregation Analysis', 'Databases', 'Contact us', 'Reports', and 'LOGOUT'. The main header reads 'SIMCADE.COM - INDUSTRIAL SOFT' and describes the site as 'Online Ingot Mold Design Solidification Simulation and Online Segregation Analysis'. A 'NAVIGATION' sidebar lists links for HOME, INGOT MOLD DESIGN, SEGREGATION ANALYSIS, MOLD DESIGN, VIDEOS - PUBLICATIONS, ABOUT, and CONTACT. The 'HIGHLIGHTS' section features a news item from February 2018 about the ICRF 2018 conference. The 'PRODUCTS AND SERVICES' section is divided into 'Online Ingot Mold Design' and 'Solidification and Segregation Analysis', each with a checkmark icon and descriptive text. A 'GET NEWS' section includes a 'Subscribe' button, and a 'CONTACT INFO' section provides a world map, company name, address, email, and phone number. The browser's taskbar at the bottom shows the system tray with the time 7:32 AM.

Ingots for Forged Plates



Conclusions

Having in view the results of experiments and solidification analysis, we can conclude the following:

- to minimize A segregation in a forged bar we need an ingot with a high H/D ratio, small hot top and a steel with low C and Si and high Mo content;
- to minimize A segregation in a forged plate we need a rectangular ingot with high sides ratio;
- pouring temperature, ingot taper and Mn content have low influence on A segregation;
- exothermic material and Cr content does not have influence on A segregation.

Mold Design and A Segregation Analysis are easy to use tools available online with a PC, MAC, tablet or smart phone to design molds, analyze segregation and choose the mold function by steel grade and forged shape.

Contact

OVIDIU BOGDAN, Industrial Soft, Canada

Phone: 1-514-3425833

<http://demo.simcade.com>

bogdan@castingsnet.com