Nodule Analysis of Ductile Cast Iron Using the LECO IA44

LECO Corporation; Saint Joseph, Michigan USA

Because of their cost effectiveness and versatility, cast irons remain a popular choice for many products today. Because the graphite in gray cast iron is shaped like potato chips, items made from it can be prone to

cracking if subjected to impact. Ductile cast iron was specifically developed, in the 1940s, with its graphite in the form of spherical "nodules". This shape makes crack initiation much less likely and yields a much more ductile material; hence its name: Ductile Cast Iron.



Metallurgical Background Information

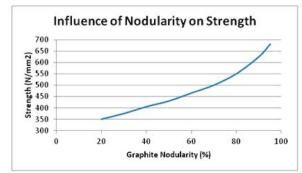
The spherical shape of the graphite in ductile cast iron does not come naturally; it requires a little help from man to make that happen. The formation of nodules is achieved by the addition of a "nodulizing" element to the molten metal bath. The most common of these elements is Magnesium, but Cerium is also used.

Quick Definitions

Nodularity: The degree to which the shapes of all graphite particles in a cast iron approach that of perfect spheres.

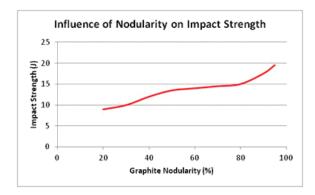
Roundness or Sphericity: A calculated value used to quantify how closely an individual particle's shape approximates that of a circle/sphere. There are a number of different methods for establishing "roundness" using, for example, nodule cross sectional area, nodule aspect ratio (L/W), nodule perimeter, etc.

Determining a ductile cast iron sample's nodularity is of great importance to a foundryman... but why? As can be seen in the plots below, the strength and impact resistance of ductile cast iron can be improved by increasing the percentage of very round graphite nodules. In general, having a large number of small, very round, nodules improves the strength, toughness and fatigue life of the final cast iron product.









To assure the quality of a particular batch of ductile cast iron, it is a smart practice to test representative samples for "nodularity" and "nodules per mm²". Usually these must meet an industry standard or a customer's own homegrown specification.

Sample Preparation

Analyzing ductile cast iron for nodularity is usually performed optically, in the as-polished condition. A typical metallographic procedure for preparing cast iron samples is detailed below:

Sample Identification	 Ductile Cast Sample holde 			Work Order N	umber: N/A	
Fixed Holder	C Single Sample					
Grinding GPX200 (10° Wheel)	Time (Minutes:Seconds)	Head Direction	Head Pressure (Pounds)	Head Speed (RPM)	Wheel Direction	Wheel Speed (FPM)
Platinum #1 812-337/ Water	2:00	CW	35	100	CCW	300
Pre-Polishing FAS Magnetic System – 10° (812-382)	Time (Minutes:Seconds)	Head Direction	Head Pressure (Pounds)	Head Speed (RPM)	Wheel Direction	Wheel Speed (FPM)
Silver Disk, 6 µm Cameo Suspension, Microid Extender, 812-340, 812-356, 811-003	2:00	CW	35	100	CCW	200
Polishing	Time (Minutes:Seconds)	Head Direction	Head Pressure (Pounds)	Head Speed (RPM)	Wheel Direction	Wheel Speed (FPM)
3µm Premium Suspension, Ultra Silk, Microid Extender, 810-997-016, 812-438, 811- 003	3:00	CW	35	100	CCW	200
1 µm Premium Suspension, Red Felt, Microid extender, 810-998-016, 812-225, 811-	0:30	cw	30	100	ccw	200

Microscopic Analysis

Analysis of the polished specimen can be accomplished manually, using a comparison wall chart; but this technique is labor intensive and highly dependent on operator skill. An automatic measurement system, such as LECO's IA44, can yield very accurate measurements in a very short time. IA44 allows an operator to analyze as many fields of the specimen as necessary, without taking the time to capture images of each field. Setting up an IA44 Nodularity Application The IA44 system uses a "Script Wizard" to walk the user through the process of creating a unique application. The first decision is to pick what type of analysis will be accomplished with the application being created:

Please select the analysis type you wish to use as a framework for your analysis routine and click on Next

Area Fraction Flake Analysis CoatingPlatingThickness Dendrite Arm Spacing Grainsize Nodularity Feature Analysis Ferrite/Pearlite Gray Iron Ductile Iron Porosity

Within the "Nodularity" application, a user has the opportunity to tailor the settings to meet specific needs. In the end, these unique settings can be saved for easy implementation at any time in the future. The IA44 system is capable of analyzing ductile cast iron specimens to meet a wide variety of standards. For example, there are six choices for how the roundness of a particle will be determined. In the screenshot below, the "ASTM Shape Factor" method has been selected.

It is also possible to exclude features from the analysis based on size or shape. There are settings that will allow for faster analysis of samples when time is in short supply. These include the "Skip Threshold Page After First Image" and the "Skip Edit Spots" check boxes. Also included in the settings are particle size limits (to filter out very small features) and a "Roundness Cut-off" value with which the % Nodularity is calculated.

	1 and 1 and 1			Object / ent Area of	Cirde
	dit/Add Bins	13	71	57	105
10					within
1000000	0	the fol	lowing ra	inge	
		Upper	Limit:	1000	%
		Lower	Limit:	o	%
um		Threshold	Туре		
	6	Col	or	🖲 Mon	ochrome
ixels to th	m from the	Passes			
Right:	0	Pace			Auto
Bottom:	0	F 635.			AUto
undness v	alue of				
	10 1000000 um ixels to tri Right: Bottom: bottom: careest care	10 10000000 um ixels to trim from the Right: 0 Bottom: 0 e After First Image terest : Data undness value of all be counted	10 13 10 Include 10000000 Upper Image: State of all be counted Include 10 Include 10 Include 10 Include 10 Include Image: State of all be counted Image: State of all be counted	10 13 71 10 Include detects the following rain of the following ra	13 71 57 10 Include detected objects the following range 10000000 Upper Limit: 1000 Image: Include detected objects the following range Upper Limit: 1000 Image: Include detected objects the following range Upper Limit: 1000 Image: Include detected objects Include detected objects Upper Limit: 1000 Image: Include detected objects Include detected objects Include detected objects Upper Limit: 1000 Image: Include detected objects Include detected objects Include detected objects Include detected objects Image: Include detected objects Include detected objects Include detected objects Include detected objects Image: Include detected objects Include detected objects Include detected objects Include detected objects Image: Include detected objects Include detected objects Include detected objects Include detected objects Image: Include detected objects Include detected objects Include detected objects Include detected objects Bottom: Image: Include detected objects Include detected objects Include detected objects Include detected objects Image: Include

For all IA44 applications, the user has the choice of creating a report, or simply viewing the results when the analysis is complete. In the example below, an Excel report template named "Nodularity-MW-10" has been selected to report the analysis results:

Generate Report	C:\PAXIT\Reports\Wodulari	ty-MW-10.XLT
	• Full Report	O Quick Report

When the user is ready to start the analysis, the assigned script bar button is pressed:



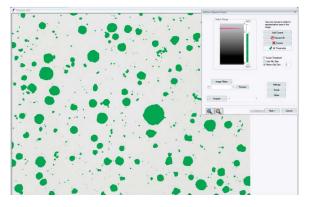
Pressing the button initiates the nodularity application and opens the appropriate camera interface. Prior to analyzing the first field of view, the user is

prompted for sample information. The entries made here will automatically appear on the finished Excel report.

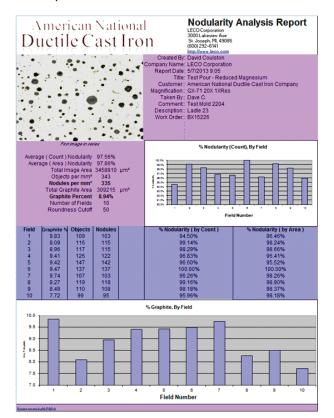
•	™ @ B		2.2
			-
			R
	Field title	Will be saved with	300
•	TITLE:	Test Pour - Reduced Magnesium	16
	Customer:	Mark West Ductile Cast Iron Company	1.00
	Magnification:	GX-71 20< 1XRes	
	Taken By:	Dave C.	
	Comment:	Test Mold 2204	et .
	Description:	Lade 23	
	Work Order:	B×15226	
5		ALLY, If unchecked, apply to ALL	
		with filename on import	
	C oronae rires		
	Dandar Tanadata		
2			
s.	0 verlay image w	ith videotext template	
ŝ		ith videotext template	
	- Overlay Template -		



From this point forward, the analysis process proceeds quickly. As a sample field is brought into view, it is checked for focus and illumination, the ANALYZE button is pressed and the thresholded objects are automatically measured and each one's size, roundness and area are measured.



This process is repeated until the prescribed number of fields are analyzed. After the last field is analyzed, the data is automatically exported to the Excel template and the report is created:



LECO Corporation 3000 Lakeview Avenue • St. Joseph, MI 49085 • Phone: 800-292-6141 • Fax: 269-982-8977 info@leco.com • www.leco.com • ISO-9001:2008 HQ-Q-994 • LECO is a registered trademark of LECO Corporation.