Porosity Analysis of Cast Aluminum Using the LECO IA44

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In an aluminum foundry, the met lab will often be asked to check an aluminum sample for "porosity". To do this, they will usually need to section, mount, grind, and polish the sample, then do an analysis using LECO's IA44 image analysis system. But where do pores come from?

Metallurgical Background Information

Metals are found – in some form – naturally occurring in the earth. Usually, they are extracted in the form of ore, which is refined and processed in a variety of ways to produce usable materials. Metals are available for manufacturing use in a wide range of shapes and forms (e.g., Bar, sheet, strip, wire, plate, etc.). Casting metals (i.e., pouring them as liquids into molds and allowing them to solidify) offers the advantage of quickly creating a form that is close to the desired final shape. This avoids a lot of expensive fabrication costs.

Forming Pores

As liquid metal solidifies in the foundry, a couple of things are working to form porosity (holes) in the finished product. The first one we will talk about is "shrinkage"; the second is "gas".

Porosity from Shrinkage
As a liquid metal cools, its density increases (it shrinks a little bit for every degree it cools). This is not a problem, since the liquid metal is free to move about and rearrange itself.

| % Contraction Liquid to Solid	
Contraction (%)	
Aluminum	7.1
Zinc	6.5
Al-4.5% Cu	6.3
Gold	5.5
White iron	4-5.5
Copper	4.9
Brass (70-30)	4.5
Magnesium	4.2
90% Cu-10% Al	4
Carbon steels	2.5-4
Al-12% Si	3.8
Lead	3.2

In most cases, when a metal goes from liquid to solid, there is a large increase in density (specific gravity) and a correspondingly large amount of shrinkage. With aluminum, this shrinkage is greater than 7% by volume (see table above). As space becomes available by the shrinking metal, holes–or "pores"–are formed.

When shrinkage pores appear in a slowly solidifying metal, they are immediately filled with nearby liquid metal. However, when molten metal is not available (e.g., when nearly all of a volume is solid) pores become permanent. As you might guess, pores in the metal tend to weaken it.

Porosity from Gas
Molten metal is able to absorb a significant amount of gas (e.g., Oxygen, Nitrogen and Hydrogen). In most cases, the higher the temperature, the more gas can be absorbed (similar to the solubility of sugar in hot tea versus iced tea). As a molten metal cools, if it is saturated with a particular gas, any extra gas will be released. As long as the metal is molten, this process proceeds easily. As the metal solidifies (usually from the outside in) it loses its ability to get rid of this gas; this leads to pores in the fully solidified casting. These pores are filled with gas and not just empty space. As with any pores, these degrade the strength and ductility of the finished casting.
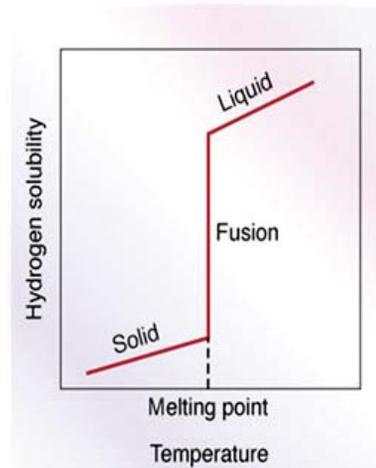
Solubility of hydrogen in aluminum. Note the sharp decrease in solubility as the molten metal begins to solidify.

Quick Definition

Solubility: The capacity to dissolve; the extent to which one substance is able to dissolve in another.

Sample Preparation

Analyzing cast aluminum for porosity is usually performed metallographically, in the as-polished condition. A typical metallographic procedure for cast aluminum samples is detailed below:

Sectioning: MSX255M2 - Cam-Lock vises and 10" SiC Abrasive Blade (P/N 810-313-010)

Mounting: PR25 / 1.25" diameter - Black Bakelite (P/N 811-111)

☑ Fixed Holder   ☐ Single Sample

Grinding GPX200 (10" Wheel)	Time (Minutes:Seconds)	Head Direction	Head Pressure (Pounds)	Head Speed (RPM)	Wheel Direction	Wheel Speed (FPM)
240 grit SiC 812-208-PRM / water	1:00	CW	30	100	CCW	250
400 grit SiC 812-212-PRM / water	1:00	CW	30	100	CCW	250
600 grit SiC 812-214-PRM / water	1:00	CW	30	100	CCW	250
800 grit SiC 812-218-200 / water	1:00	CW	30	100	CCW	250

Polishing	Time (Minutes:Seconds)	Head Direction	Head Pressure (Pounds)	Head Speed (RPM)	Wheel Direction	Wheel Speed (FPM)
3μ Premium Suspension, UltraSilk Cloth, Microid Extender 810-997-016, 812-438, 811-003	3:00	CW	30	100	CCW	200
1μ Premium Suspension, Red Felt, Microid extender 810-998-016, 812-225, 811-003	1:00	CW	30	100	CCW	200
0.05μ Colloidal Silica, Imperial cloth, 812-110-300, 812-226-010	1:30	CW	25	75	CCW	150

Microscopic Analysis

Analysis of the polished specimen can be accomplished manually, using a grid overlay; but this technique is labor intensive and prone to operator error. 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 Porosity 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:
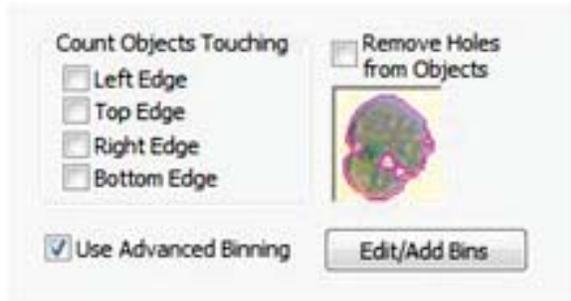

Within the "Porosity" application, a user has the opportunity to tailor the settings to meet specific needs. In the end, these unique settings can be saved for easy implementation any time in the future. For this example, we will be utilizing a feature called "Advanced Binning" to measure pores and place them in size classifications (or "bins").

Bins can be created based upon a feature's shape or area; we will be binning based on the feature's "Max Feret" (a sort of longest dimension measurement). In the Advanced Object Filter Settings window, five "bins" are established:

For all IA44 applications, the user has the choice of creating a report, or simply viewing the results when the analysis is complete. Here, an Excel report template named "Porosity – GACC" has been selected to report the analysis results:
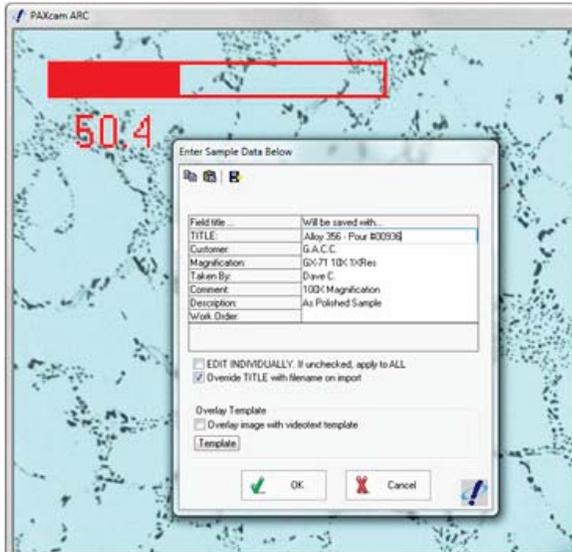

When the user is ready to start the analysis, the assigned scriptbar button is pressed:
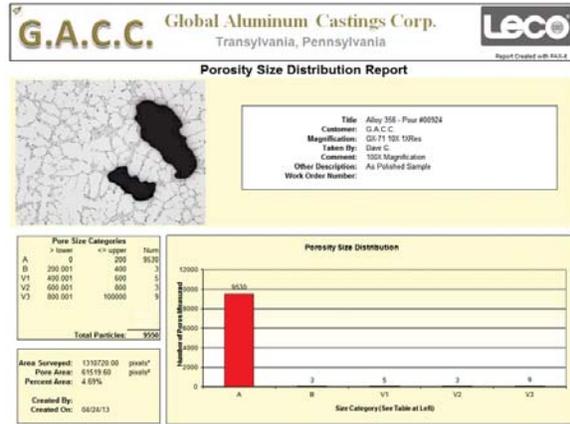

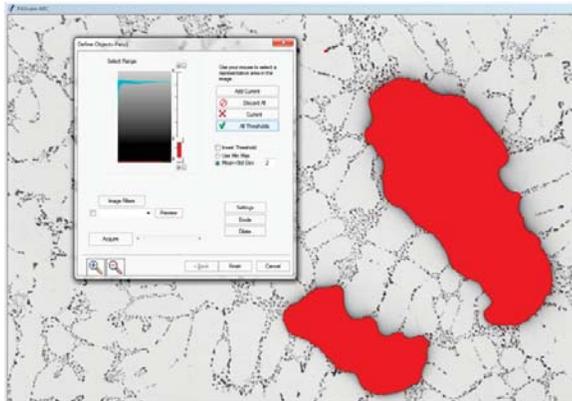Pressing the button initiates the porosity application and opens the appropriate camera interface.

Prior to analyzing the first field of view, the user is prompted for sample information. The entries made will automatically appear on the finished Excel report.

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 categorized by Maximum Feret.

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

Metallographic Application Note