MSi Investigative Summary

BACKGROUND

Two (2) sections removed from a cast iron cylinder head were submitted to our failure analysis lab for a metallurgical investigation. The submitted sections were identified as Sample #1 and Sample #2. Both samples exhibited sub-surface defects that were exposed during machining or cutting of the wall section. The cylinder head was reportedly poured with gray iron into a green sand mold. Hot box cores were als o utilized, which were coated with a water based coating. We were requested to perform a metallurgical failure analysis to determine the nature of the defects and provide the following summary.

SAMPLE IDENTIFICATION

Description	Material	Sample ID
Cylinder Head	Gray Cast Iron	Sample #1 and Sample #2

PERFORMED TESTING

Visual and Stereoscopic Examination
Metallographic (Microstructure) Examination
Energy Dispersive Spectroscopy Analysis
Chemical Testing

CONCLUSIONS

1. Based upon the performed failure analysis service identified the cause of the sub-surface defects (voids) was gas-related. The shape, size, and interior microstructure characteristics indicate the defects formed from nitrogen gas. The origin of the nitrogen is most likely an external source, which would include nitrogen-bearing materials accumulating in the green sand system (molds), improperly cured cores, and core resins.

2. Visual and metallographic examination of the defect profiles revealed sub-surface cavities that varied from irregular and fissure-type in Sample #1 to relatively smooth exhibiting an exuded ball of metal at mid-point in Sample #2. The defect profiles were partially lined with a discontinuous layer of carbon. The flake graphite within the matrix extended into the defect cavities. These features are characteristic of nitrogen related gas porosity.

CONCLUSIONS (cont.)

3. The nitrogen content of the iron was 70 ppm, which was within a normal range. However, the titanium content of the iron was only .006%. We respectively recommend the use of a graphitizing inoculant containing a substantial amount of titanium, approximately 9.5%. Proper use will result in titanium levels of .02 – .04%, which will combine with excessive nitrogen to form titanium nitrides and minimize porosity from nitrogen gas.

SUMMARY of TEST RESULTS

Visual & Stereoscopic Examination

1. Visual and stereoscopic examination of Samples #1 and #2 revealed sub-surface cavities that were irregular and fissure-type in #1 to relatively smooth with an exuded ball of metal at mid-point in Sample #2. (See Photos 1 – 3)

2. The defect profiles in Photos 2 and 3 were sectioned and further examined using metallographic methods.

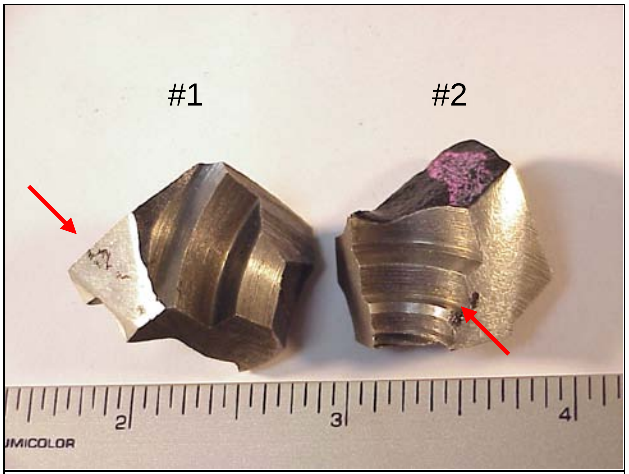

Photo 1: View of the submitted cylinder head samples #1 and #2. Arrows indicate defect locations

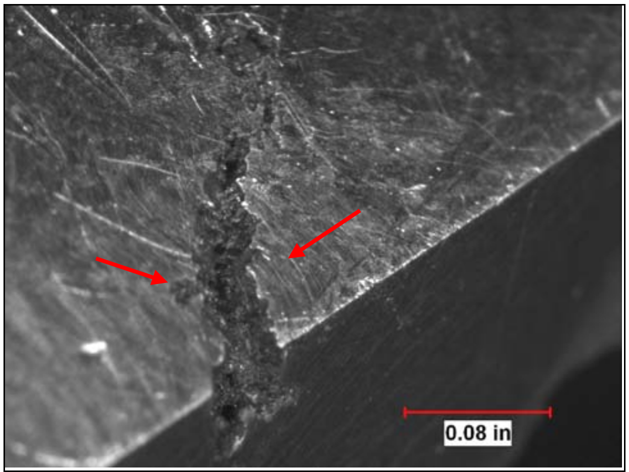

Photo 2: Close-up view of fissure-type defect on sample #1 between arrows. Mag: 15X

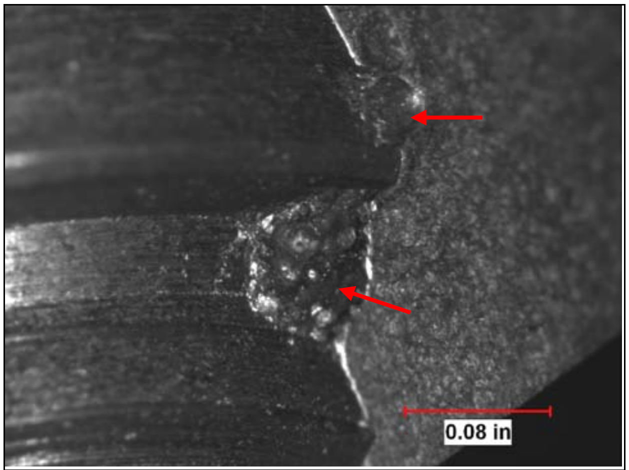

Photo 3: Close-up view of gas-type defect on sample #2, which included a smooth surface and exudation of metal near mid-point. See Arrows. Mag: 15X

Metallographic Examination

1. Examination of the two defect profiles verified the fissure-type conditions of Sample #1 and the relatively smooth surface and exuded ball of metal in Sample #2. Both were partially lined with a discontinuous layer plus graphite flakes in the matrix extended into the cavities, which is characteristic of nitrogen related gas porosity. (See Photos 4 – 7)

2. The microstructure of the two sections consisted of fine pearlite and small amounts of ferrite, which was characteristic of Class 30 or Class 35 gray iron. (See Photo 6)

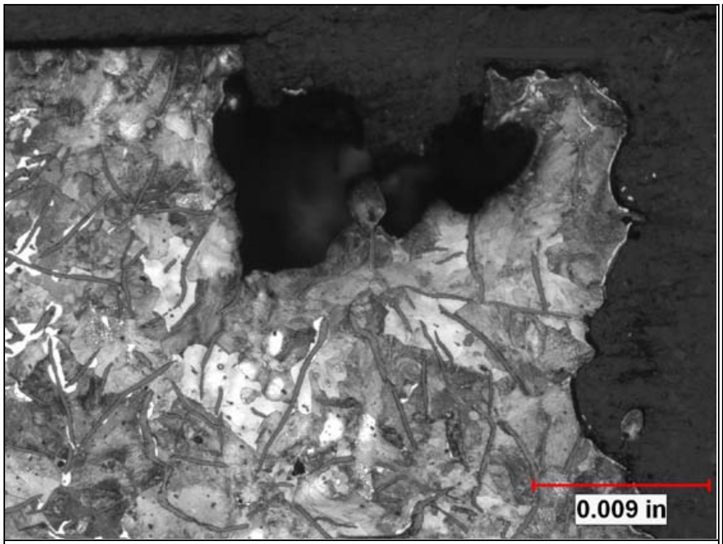

Photo 4: Mag: 100X; Etchant: 3% Nital
Sample #1: Defect profile was irregular and fissure-type

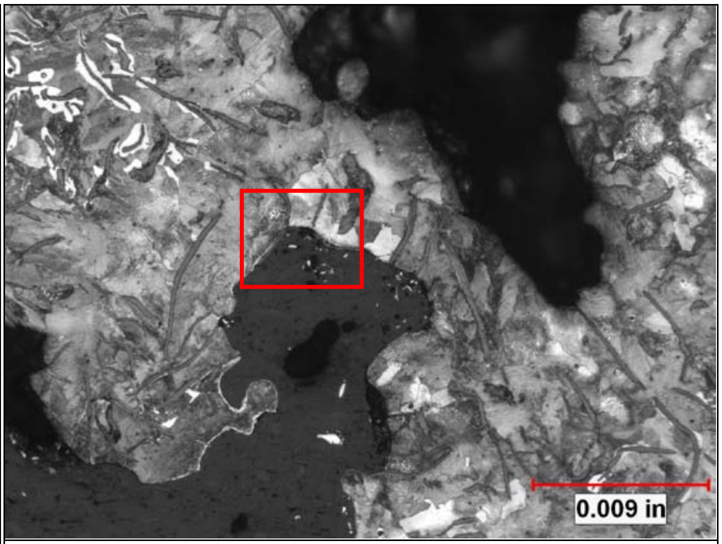

Photo 5: Mag: 100X; Etchant: 3% Nital
Sample #1: Defect profile lined with discontinuous layer.

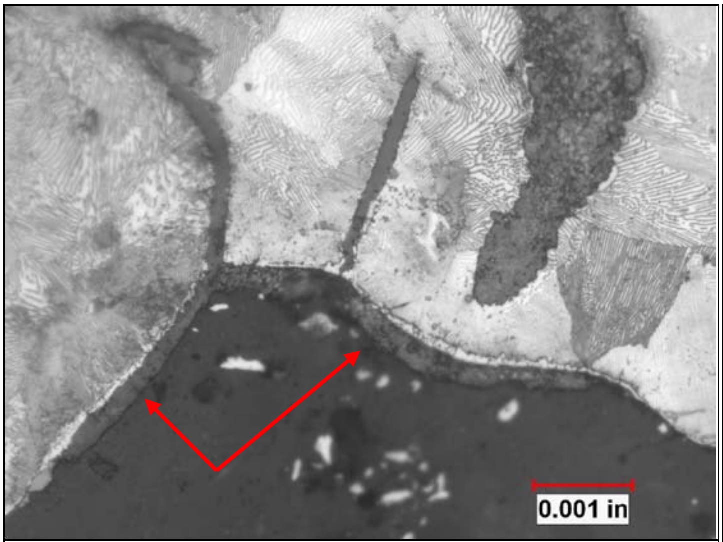

Photo 6: Mag: 500X; Etchant: 3% Nital
Close-up view of inset in Photo 5 showing a layer lining the defect.

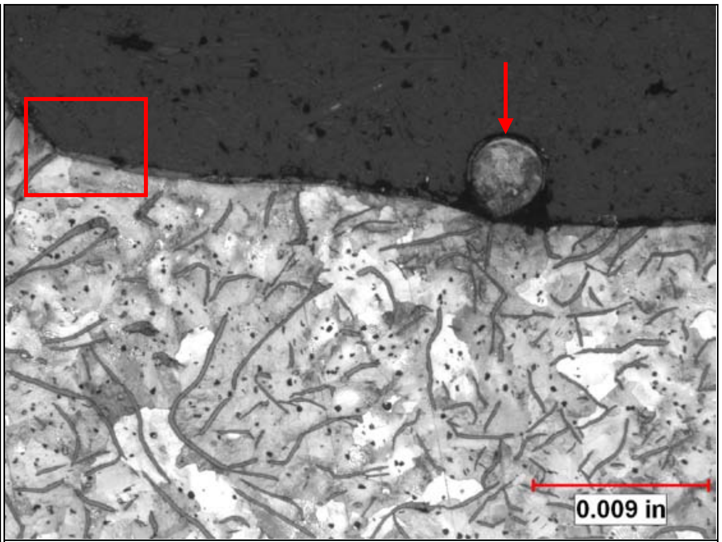

Photo 7: Mag: 100X; Etchant: 3% Nital
Sample #2: Exuded metal ball at midpoint of defect.

Metallographic Examination (cont.)

3. The discontinuous layer of material lining the defect profiles as seen in Photos 6 and 7 was subjected to EDS analysis.

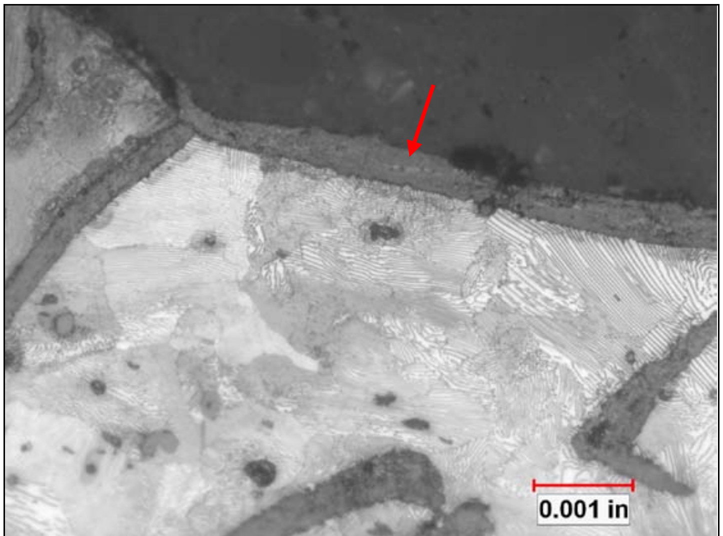

Photo 8: Mag: 500X; Etchant: 3% Nital
Close-up view of inset in Photo 7 showing layer lining the defect.

Energy Dispersive Spectroscopy Analysis

1. EDS analysis of the discontinuous layer lining the defects revealed a major elemental peak of carbon and minor elemental peaks of for silicon, aluminum, iron, calcium, and oxygen. The results indicate the layer was primarily graphite (carbon), which is a common characteristic of a gas cavity formed from nitrogen gas.

2. See attached Figure 1.

Chemical Testing

1. Sample #1 was tested for titanium and nitrogen content. Chemical test results indicate the nitrogen content was .007% (70 ppm), which is within the normal range of 20 – 80 ppm for gray iron. The results suggest the most likely source of nitrogen gas was related to nitrogen-bearing materials accumulating in the green sand system (molds), and possibly improperly cured cores, or core resins.

2. The titanium result of .006% indicates an increase to .02 – .04% should be considered to combine with any excessive nitrogen and minimize nitrogen gas porosity.

3. The results are shown in attached Table 1.

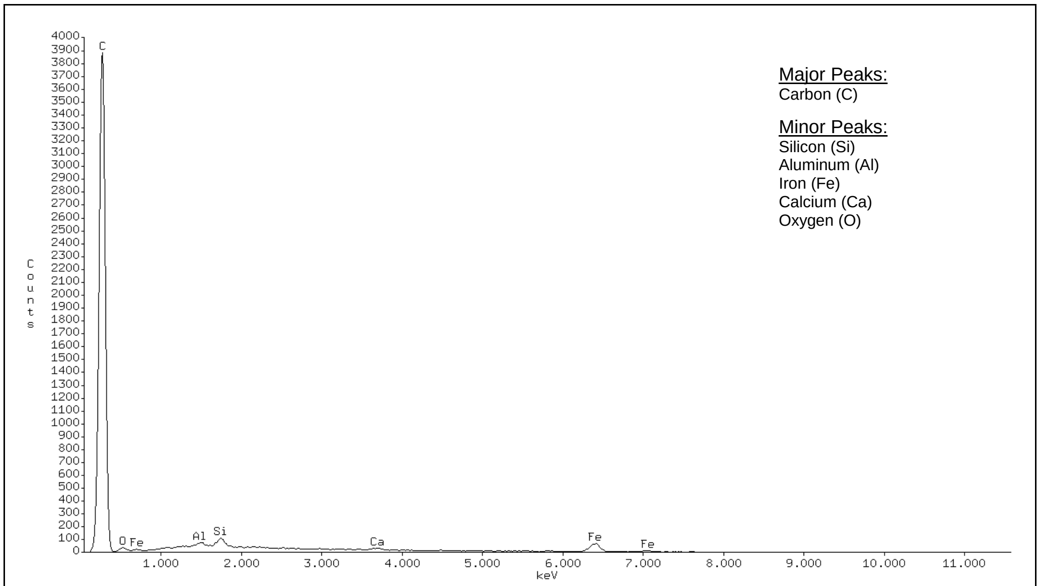

Figure 1: EDS spectrum of the discontinuous layer lining the defects.

Table 1

CHEMICAL TESTING ∗

Element	Results
Titanium	.006
Nitrogen (ppm)	70

∗ Testing performed in accordance with ASTM E1479, E1019.