MSi Testing & Engineering, Inc.
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"Failure analysis testing performed by MSi Testing & Engineering on two ductile iron brake heads did not identify any evidence of detrimental material conditions contributing to the component fractures."

Key Word: Failure Analysis Testing
Secondary Key Words: Failure Analysis Services, Steel Failure Analysis

MSi Investigative Summary

BACKGROUND

Two (2) ductile iron castings identified as Brake Heads were submitted to our laboratory for failure analysis testing. Sample #1 exhibited a complete fracture of the brake shoe arm near the inside pocket location of the head. Sample #2 exhibited a partial crack between an outer rib of the brake shoe arm and head.

The submitted samples were vertically cast as Ductile Iron Grade 65-45-12 per ASTM A536 with a typical hardness of 156 – 217 HBW. Both samples were installed and in-service for an unknown period of time. No further background information was available.

We were requested to determine if any detrimental material or defect conditions could have contributed to the failure of Sample #1. The crack of Sample #2 was exposed and subjected only to visual examination. The failure analysis services requested by the client were only for the fracture of Sample #1.

SAMPLE IDENTIFICATION

Part Name	Ductile Iron Grade	Specification
Brake Head	65-45-12	ASTM A536

PERFORMED TESTING

Visual and Stereoscopic Examination
Metallographic (Microstructure) Examination
Tensile Testing
Charpy Impact Testing (Un-notched)
Hardness Testing
Chemical Testing

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CONCLUSIONS

1. Based upon the performed steel failure analysis, it is our opinion the cracking on both samples initiated from common as-cast surface conditions of the outer rib of the brake shoe arm, and inside pocket location of the head. Oxidation (corrosion) of exposed fracture surfaces prohibited interpretation of the original fracture features. It is our opinion that the failure of Sample #1 was not related to any detrimental material defect conditions, such as internal porosity (gas or shrinkage cavities), excessive dross or surface stringers, degenerated graphite, or intercellular carbides.

2. Sample #1 conformed to the specified requirements for Ductile Iron Grade 65-45-12 per ASTM A536. Tensile and hardness testing of material removed adjacent to the fracture verified the casting conformed to the tensile requirements for Grade 65-45-12. Un-notched Charpy impact results provided additional support of properly manufactured ductile iron.

3. Visual examination of exposed and cleaned fractures revealed similar sites of initial cracking along the inner pocket radius location of the head and arm. The fracture features of Sample #1 exhibited a chevron pattern from the pocket radius, which indicated the area was the site of initial cracking. The exposed fracture surface of Sample #2 revealed no informative evidence due to oxidation (corrosion).

4. Metallographic examination of sections through the fracture of Sample #1 revealed an “as-cast” surface condition along the cast surface that consisted of some magnesium-silicate stringers (dross inclusions) to a depth of .002”. The amount and depth of the dross stringers were not considered excessive. However, the stringers potentially serve as stress-concentrators during rapid loading and could serve as sites for fatigue cracking.

5. The matrix microstructure of Sample #1 consisted of 7 – 10% pearlite in a matrix of ferrite, which was characteristic of Grade 65-45-12 ductile on the lower end of the typical hardness range of 156 – 217 HBW. The graphite morphology consisted of 90% minimum Type I and II graphite, primarily sizes 6 and 7. The nodule count varied between 75 – 100/mm^2. No evidence was observed of any intercellular carbide, carbide network, or any other detrimental material defect conditions that could have contributed to the failures.

6. The chemical composition results of Sample #1 indicated a carbon equivalent (CE) value of 4.54. In our opinion, the silicon content of 2.90% was aimed for

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a predominantly ferritic microstructure with some pearlite, which was observed. No alloying elements were utilized to promote increased amounts of pearlite in the microstructure. Small amounts of copper or tin or combinations of both could be utilized to safely increase the amount of pearlite in the microstructure to 10% or greater.

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SUMMARY of TEST RESULTS

Visual and Stereoscopic Examination

1. Examination of the submitted brake head castings revealed a complete fracture of Sample #1 and cracking of Sample #2 from the brake shoe arm and the inner pocket location of the head. The amount of oxidation of the fracture was significant and after cleaning masked some of the fracture features. (See Photos 1 and 3)

2. Visual examination of exposed and cleaned fractures revealed similar sites of initial cracking along the inner pocket radius location of the head and arm. The fracture features of Sample #1 exhibited a chevron pattern emanating from the pocket radius, which indicated the area was the site of initial cracking. The exposed fracture surface of Sample #2 revealed no informative features due to corrosion. (See Photos 2 and 4)

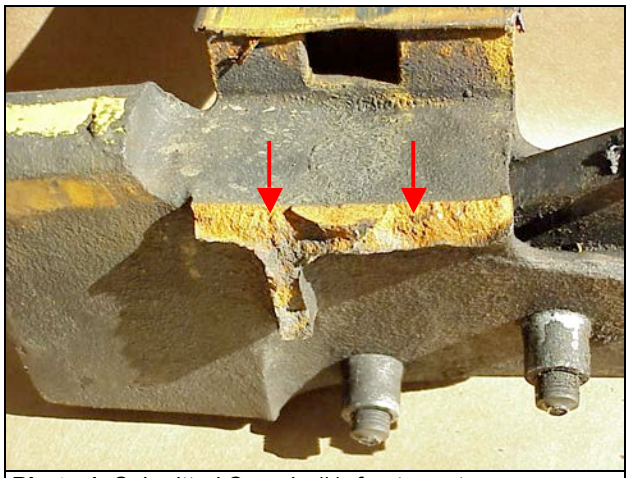

Photo 1: Submitted Sample #1, fracture at arrows.

Photo 2: Close-up view of fracture and chevron pattern, which indicated cracking initiated from inside pocket.

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Photo 3: Submitted Sample #2, cracking at arrow.

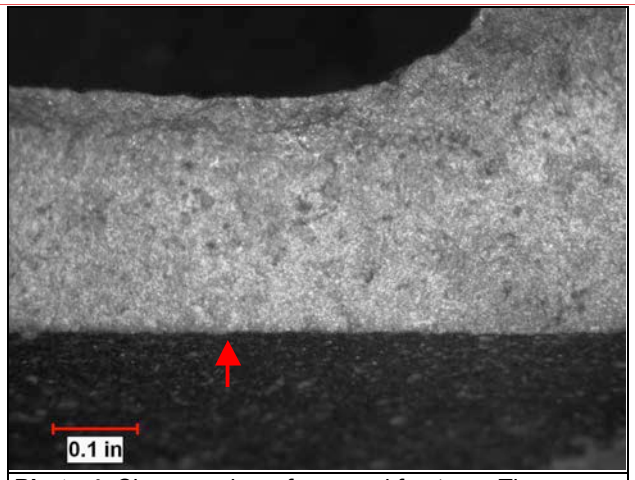

Photo 4: Close-up view of exposed fracture. The arrow indicates the inside pocket surface. Mag: 7X

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Metallographic Examination

1. Transverse sections were removed through the fracture of Sample #1 at two locations indicated with arrows in Photo 2. Examination of the graphite morphology showed a uniform distribution of graphite nodules, typical of properly cast ductile iron. The graphite characteristics are described in the following table and shown in Photos 5 and 6.

Sample	% Nodularity	Nodule Count/mm^2	Form Type	Size
#1	> 90%	75 – 100	I/II	6 - 7

2. The matrix microstructure of Sample #1 consisted of 7 – 10% pearlite in a matrix of ferrite. (See Photo 6)

3. The surface microstructure along the inner pocket location of Sample #1 contained some magnesium-silicate stringers (dross inclusions), which were not considered excessive. The most severe dross stringers were measured to a depth of .002" below the surface. (See Photo 7 on the following page)

4. No evidence was observed of any intercellular carbide, carbide network, porosity, or any detrimental material defect conditions that could have contributed to the failure. (See Photo 8 on the following page)

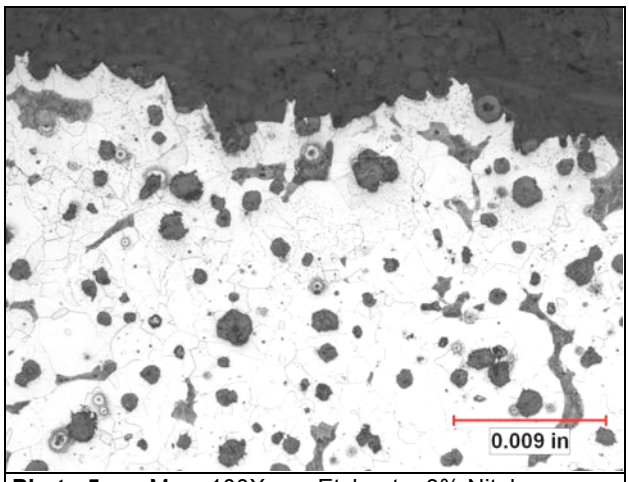

Photo 5: Mag: 100X; Etchant: 3% Nital
Sample #1 - fracture surface, Type I & II graphite, size 6 and 7.

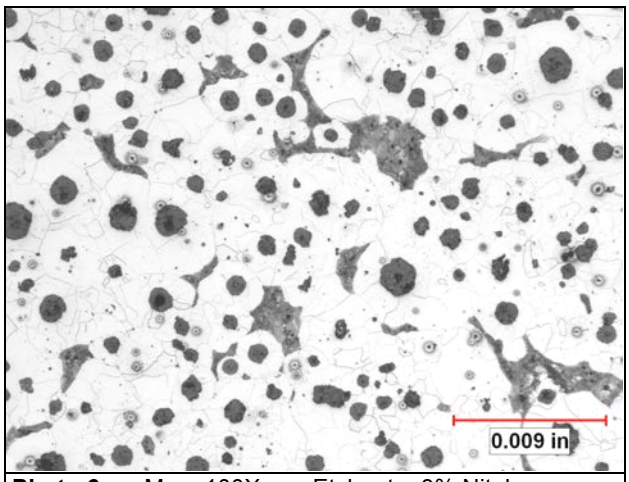

Photo 6: Mag: 100X; Etchant: 3% Nital
Sample #1 – at core, Type I & II graphite, size 6 and 7.
Matrix: 7 – 10% pearlite in ferrite.

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Metallographic Examination (cont.)

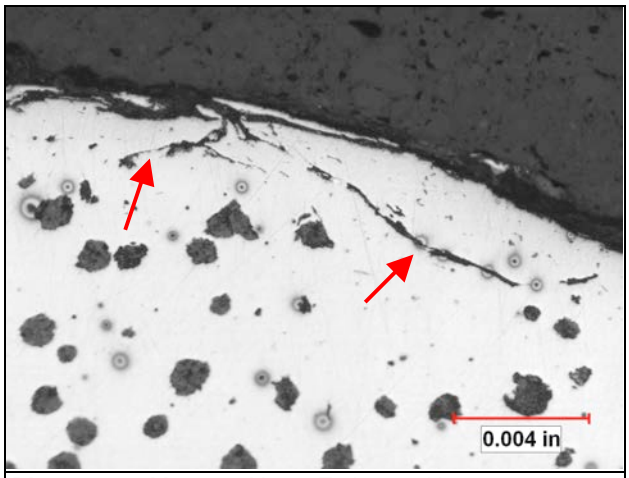

Photo 7: Mag: 200X; Etchant: None
Sample #1 – Magnesium-silicate stringers to a depth of .002" below the surface.

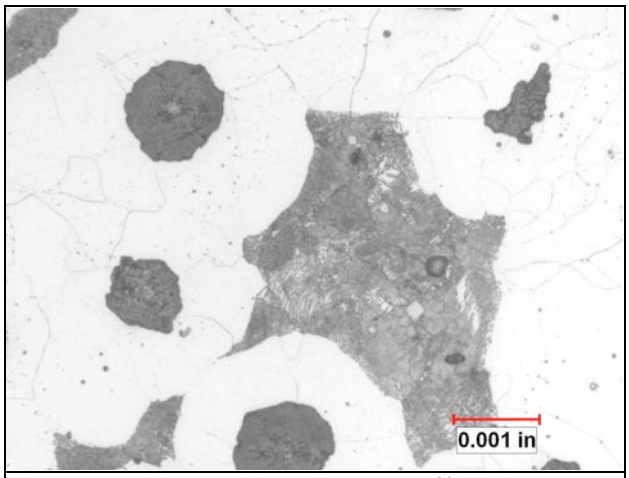

Photo 8: Mag: 500X; Etchant: 3% Nital
Sample #1 – Matrix of ferrite and pearlite, no evidence of carbide or intercellular carbide.

Tensile Testing

1. Tensile testing revealed Sample #1 conformed to the tensile requirements for Grade 65-45-12 per ASTM A536.

2. The results are shown in Table 1 attached.

Hardness Testing

1. Hardness testing was performed at the core location adjacent to the fracture of Sample #1. A hardness result of 167 HBW was within the typical range of 156 – 217 HBW for Grade 65-45-12 ductile. No requirements are listed in the ASTM A536 specification for Grade 65-45-12.

2. The results are shown in Table 2 attached.

Charpy Impact Testing

1. Un-notched Charpy impact specimens were prepared from material removed from the head of Sample #1. The results averaged 65 ft-lbs. Charpy impact testing is not a requirement in ASTM A536 and is provided for informational

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purposes.

2. The results are shown in Table 3 attached.

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Chemical Testing

1. The chemical composition results of Sample #1 indicated a carbon equivalent (CE) value of 4.54. No alloying elements were utilized to promote increased amounts of pearlite in the microstructure.

2. The results are shown in Table 4 attached.