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Cast Iron Failure – Case Study

By

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Introduction

One of the more difficult situations faced by many manufacturers is trying to purchase cast irons that meet their specifications from a new supplier. This is particularly true when purchasing from a low cost supplier. This case study involves a cast iron hub that failed shortly after being placed in use. The hub was from a second order of castings, supposedly from the same foundry as the original order of castings which performed as expected. The castings were specified and certified to be 80-55-06 ductile cast iron. Prior to machining, the casting weight was 75 pounds. The failed casting was examined by visual examination, hardness testing, and metallographic examination.

Visual Examination

Figure 1 – Broken Casting as Received from Client

Figure 2 – Hub Flange Fracture

Figure 1 shows the broken casting as received from the client. The fracture occurred on the interface between the flange and the shaft. Figure 2 shows the fracture surface on the flange side. The fracture appears to be brittle, and the material is similar in appearance to gray cast iron, not 80-55-06 ductile cast iron.

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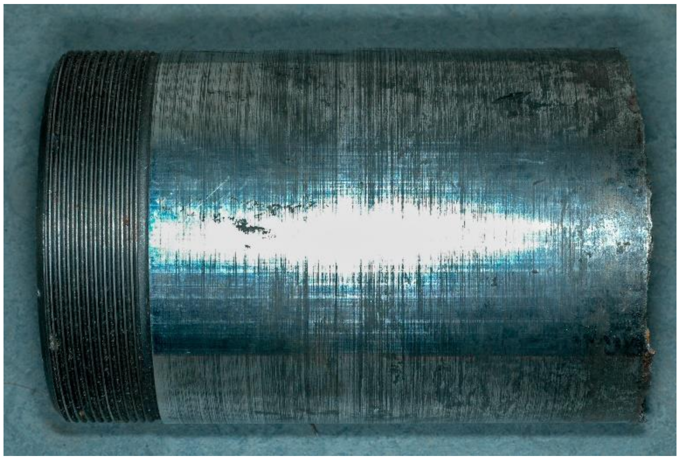

Figure 3 - Axle

Figure 4 – Fracture Surface on Axle

Figure 3 shows the broken axle shaft. The fracture surface, shown in Figure 4, has the typical appearance of fractured gray cast iron, which is brittle fracture.

Hardness Testing

The hardness testing was done according to ASTM E384, using a Vickers indenter and a 500 gram load. The results of the testing are given in the table that follows. The test results were converted to Brinell Hardness Number, (BHN). The specified material, 80-55-06, has a hardness range between 190 and 260 BHN. None of the hardness readings were within the specified range for 80-55-06 ductile cast iron.

Hardness Test Data (Brinell Hardness Number)					
Sample	Vickers	Std. Dev.	Maximum	Minimum	Hardness
Flange	161.00	13.38	185.00	143.00	152.7 BHN
Fracture - Axle	114.00	40.98	161.00	70.30	104.86 BHN
Fracture - Flange	125.00	24.01	163.00	101.00	116.6 BHN
Axle - Threads	189.00	12.97	211.00	167.00	180.2 BHN

Metallographic Examination

Metallographic cross sections were taken from the flange, flange fracture area, axle fracture area, and the threaded end of the axle.

Figure 5 shows the compacted or vermicular graphite found in the flange. Volume 1, Tenth Edition, page 56, of the Metals Handbook states, “It has been inadvertently manufactured in the past in the process of producing ductile iron, as a result of under treatment with magnesium or cerium.” The ferrite microstructure indicates that the manganese content is low. Manganese will help to form pearlite, resulting in higher hardness and strength.

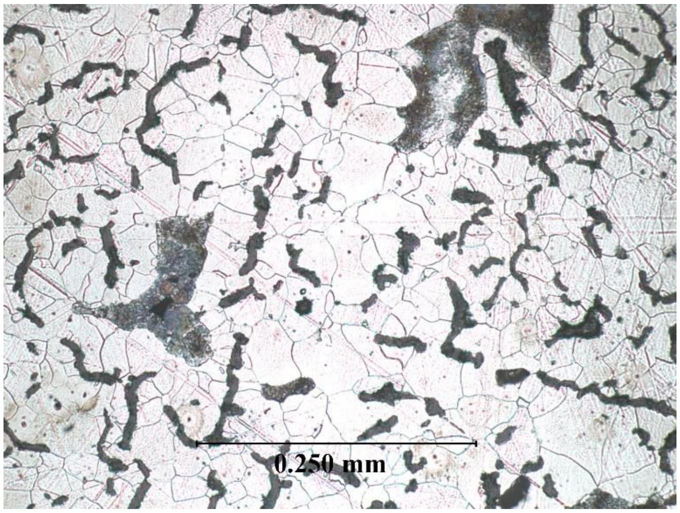

Figure 5 – 200X Microstructure of Flange Material

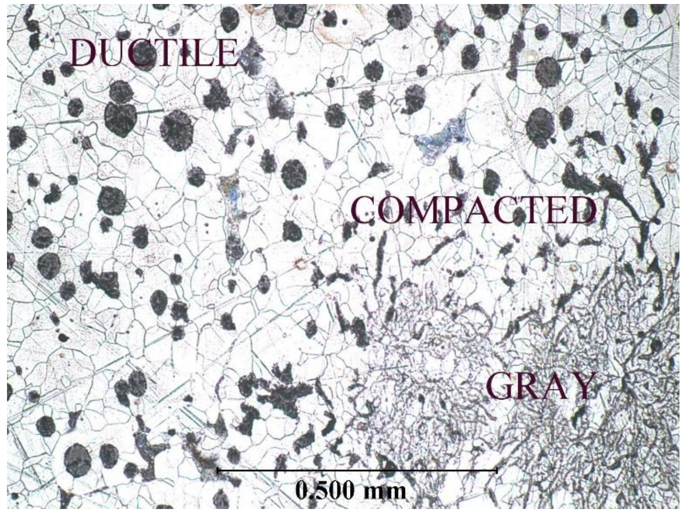

Figure 6 – 100X Microstructure Flange Fracture Area

Figure 6 shows the microstructure near the flange fracture surface. The microstructure contains three ferritic cast irons, ductile in the upper left, compacted through the center, and gray cast iron in the lower right.

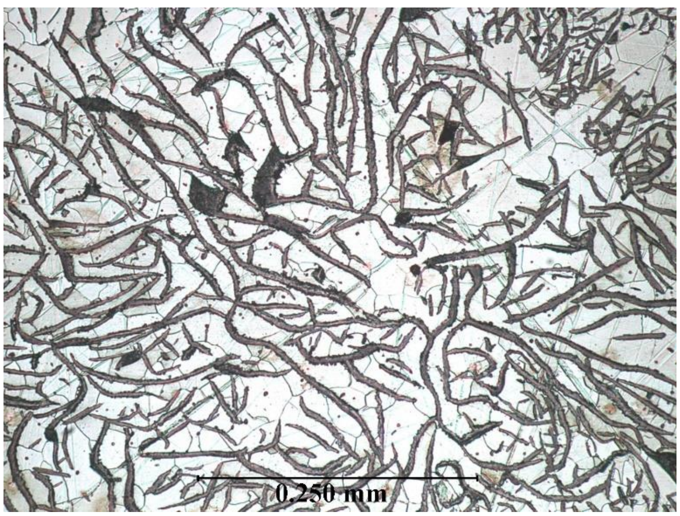

Figure 7 – 200X Ferritic Gray Cast Iron – Flange Area of Fracture

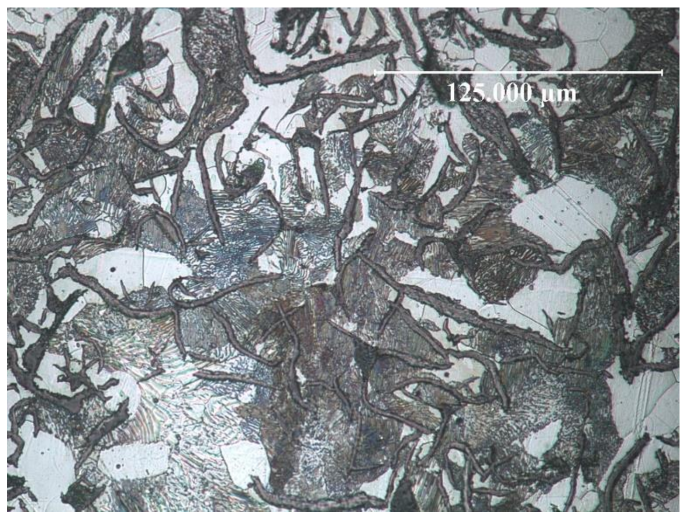

Figure 8 – 400X Pearlitic Gray Cast Iron – Axle Area of Fracture

Ferritic gray cast iron microstructure is shown in Figure 7, which is typical of Class G1800 cast iron. The hardness of 105 BHN indicates that the gray cast iron areas of the casting were Class G1800, which is typically used for applications where vibrational damping is required, and minimal strength characteristics are not required.

On the axle side of the fracture, the cast iron was pearlitic, Figure 8, indicating a different cast iron. The microstructure indicates a G3000 gray cast iron at this location. The extreme difference in microstructures indicates that more than one heat of cast iron was used in producing this casting.

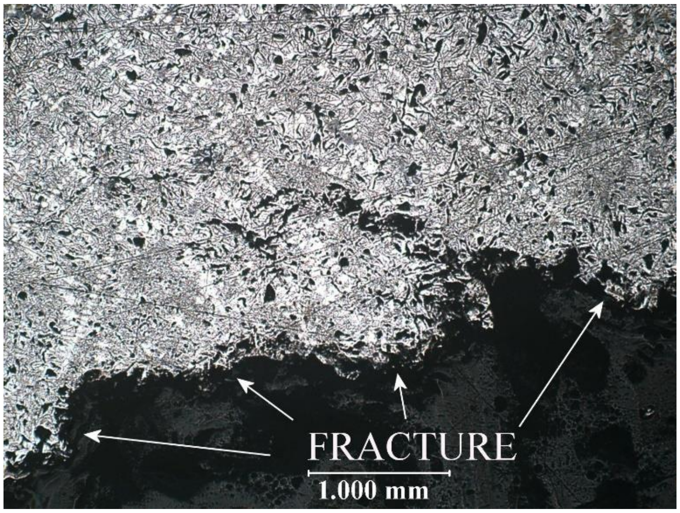

Figure 9 – 25X Fracture Section on Axle Side

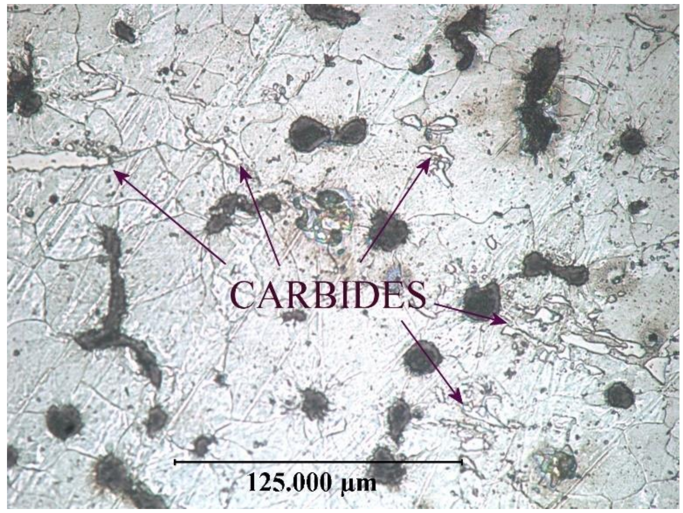

Figure 10 – 400X Carbides near Axle Threads

The microstructure along the fracture surface was gray cast iron. Figure 9 shows one location. The presence of graphite flakes indicates that there were no inoculating elements present, either due to them not being added prior to the pour, or the melt having been held too long.

The presence of carbides at the threaded end of the axle, Figure 10, indicates that this end of the casting cooled very rapidly, or that calcium silicate had been used for an inoculate instead of magnesium or cerium. At the fracture end of the axle there was no indication of inoculate, as indicated by the flake graphite, Figures 8 and 9. This difference in microstructure indicates a third pour was involved in making the casting.

Discussion

This casting represents the worst cast iron casting I have ever examined. It was learned after the failure analysis was completed that, between the first and second lots of castings received by this client, the supplier had changed foundries to a foundry that had a maximum melt and pour capability of 10 kilograms, or 22 pounds, and it was taking three to four pours to make the casting.

The minimal capacity of the foundry explains many of the variations in the microstructure and the inability to have control of the inoculate. There was also a lack of understanding of what was required to produce the specified 80-55-06 ductile case iron.

Cast irons are one of the widely used materials where small variations in chemistry can lead to failure of the end product. The reason for this is that the three basic types of cast iron, gray, compact, and ductile, have the same basic composition of iron, carbon, silicon, and manganese. Very small additions of magnesium, (0.03 to 0.06%), or cerium, (0.005 to 0.20%), can change the type of cast iron. These elements are volatile at casting temperatures and are short lived in the melt. Small variations in other elements can result in significant mechanical property variations within a given type of cast iron. The pouring temperature also has an effect on the graphite structure and mechanical properties of the final casting. The cooling rate after casting also affects many of the properties of the final casting. The three types of cast iron can be heat treated to modify the mechanical properties.