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Ductile Iron Society 1998 Annual Meeting Highlights

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by HANS J. HEINE, International Editor

The Technical and Operating Sessions introduced several significant and innovative procedures. Here are some of the highlights of the conference.

Of great value to quality control is the ability to test whether or not a sample of ductile iron contains a predetermined amount of magnesium. The ideal system would not be time-consuming, would operate under a minimum margin of error, and would not be costly. The so-called MgLABIIMgCUP System satisfies these requirements.

Tests within the system are conducted following magnesium treatment and inoculation to check Mg level (which is residual prior to fading) before pouring off molds. The System has the ability to determine whether sufficient magnesium remains in the liquid metal in the event that pouring is delayed. If carried out properly, each test takes less than two minutes.

As part of the process, a sample of clean metal is poured into a MgCup that contains a "carefully controlled amount of sulfur," the amount being determined by the percentage of uncombined magnesium that the specific foundry requires in its ductile iron. The MgLAB II instrument then uses long-established thermal analysis techniques to determine with confidence whether the magnesium content exceeds the nominal value of the particular MgCUP used: either 0.035 or 0.040%. If the magnesium content is higher than the nominal value, the instrument displays a "PASS" message. Should the magnesium content fall below the nominal value, a "FAIL" message is displayed on the screen (the system error is pegged at (0.003% Mg). Additional features include the following:

- The cooling curve of the sample being tested is plotted on the MgLAB II screen.
- All parameters can be configured and fine-tuned by the metallurgist conducting the test.
- Status lights show the current state of each test.
- All data from the previous 200 can be saved in memory and can be downloaded to a PC through the RS-232 port.

The theory undergirding the development of the innovative test, as explained by a company representative, goes something like this: each cup contains a precisely measured quantity of sulfur, the amount depending on the percentage of uncombined magnesium that the specific foundry requires for its ductile iron. Presently, the manufacturer offers a 0.035% and 0.040% version of the MgCUP. (The former version always contains enough sulfur to combine with 0.035% magnesium to form MgS. The same is true for the 0.040% version.) In addition, each cup also contains an accurately controlled amount of tellurium, which is determined by the necessity that the iron solidify as carbide eutectic when all the magnesium is in a combined form, as in MgS. (Tellurium is known as a strong carbide former and stabilizer.)

It should not be forgotten that identification of phases and nodularity in ductile iron is fraught with uncertainty. Thermal analysis is a low-cost method used to eliminate the uncertainty. An instrument does it all once the system is tailored to each foundry's individual needs (no training of operators is necessary).

Factors affecting the metallurgical quality of ductile iron castings:

- Metallic charge
- Effect of remelting
- Steel in charge
- Rust scrap effect on chill
- Type of melting equipment involved
- Effect of superheating (loss of nucleating effect)
- Effect of dwell (holding) time on graphitizing potential
- Chemical analysis (influence of carbon equivalent value)
- Presence of carbide stabilizers
- Inoculation effect on nodule count

When ductile iron is poured into permanent molds—a high-production, repeatable process—rapid solidification avoids porosity and results in a very "tight" structure. As a result, machinability is excellent, and there is no molding sand with inherent problems involved. The power transmission and hydraulic markets are the most important customers. The process allows very close dimensional tolerances to be held. Molds can be either air- or watercooled, and proper venting is very important. A soot coating is used to facilitate mold release. Because the metal freezes with a predominantly carbide structure, castings have to be annealed or normalized. The carbon equivalent value (CE) is held to about 4.5. Titanium additions will promote the formation of type D graphite. To enhance fluidity, the phosphorus content is kept relatively high at about 1%.

Subsequent to thermal treatment, the matrix structure will be ferritic with 300+ nodules of spheroidal graphite per square millimeter (Graphite flotation is very rare.) Molds are normally preheated. Mold life is obviously a function of the complexity of the part to be cast—it may easily vary between 5,000, or fewer,

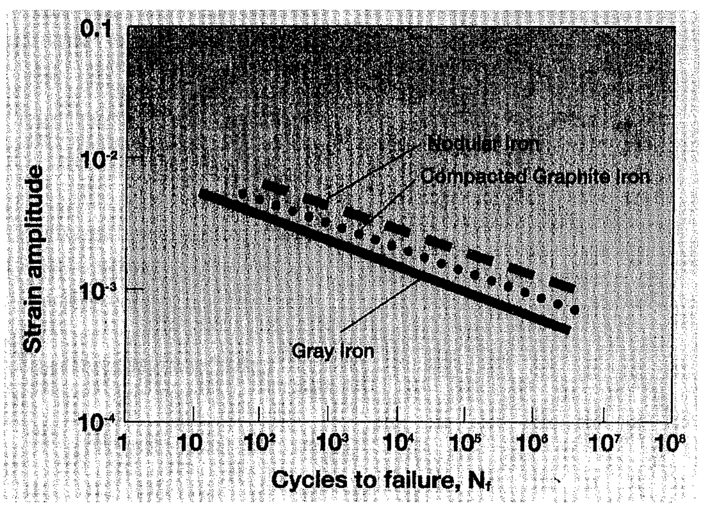

Figure 1. Comparison of typical stress-life fatigue curves for nodular (ductile), gray, and compacted graphite cast irons.

and 100,000, or more, cast components. Molds are frequently fabricated from cast iron, because casting the mold close to the finished shape can decrease machining expenditures. Pouring temperature and casting weight influence mold life. Mold design has a marked effect on mold life. For instance, variations in mold wall thickness may cause excessive stress to develop during repeated heating and cooling, which in turn may result in premature cracking. Abrupt changes in thickness—without generous fillets—also can lead to early failure.

Projections in the mold cavity contribute to reduced life because they become extremely hot, a situation which may cause deformation and mutilation when the casting is removed. Improper mold storage can lead to rusting or pitting corrosion of mold surfaces.

If the structural functions of a casting are more important than its appearance, mold life is extended.

The mold coatings used in the production of iron castings—and this is frequently not recognized—fall into two categories: an initial coating applied before the mold is placed in production, and a subsequent coating of soot (carbon), applied prior to each pouring. The initial coating, normally consisting of sodium silicate (also known in the trade as "water glass") and finely divided pipe clay, is mixed in a ratio of approximately 1 to 4 by volume with enough water to allow for spraying or brushing. Generally, for best results, this mixture is applied to heated molds (475 to 500° F).

When a cast component is subjected to repeated loads, cracks may develop in areas that are highly stressed and grow as cyclic or repetitive loading occurs. What is unfortunate is that crack initiation may occur at stress levels below the characteristic ultimate strength of the material. Failure by this mechanism is termed "fatigue failure." Fatigue cracks frequently begin at stress raisers such as abrupt changes in section thickness, notches, machining gouges, etc. Surface discontinuities also play a major role in fatigue crack initiation.

The fatigue strength of castings normally is lower than that of wrought materials (however, castings are less notch-sensitive than wrought materials).

Separately-cast test bars are frequently employed to avoid the destruction of production parts. However, judging from practical experience, the fatigue resistance of these bars usually is higher than that of most cast products due to factors such as relatively low porosity and the presence of beneficial residual surface compressive stresses. It is recommended, therefore, that test bars be machined from critical casting areas in cases where fatigue properties are important to the design engineer and metallurgist.

Periodic overstrain of a cast component affects fatigue life and may shorten it; on the other hand, residual compressive surface stress (shot peening, induction hardening, etc.) will positively affect fatigue strength and crack initiation. The type of graphite seen in the microstructure also affects fatigue strength. Unfortunately, however, there is not a sufficient amount of authoritative information available on ductile iron to allow a designer to design without paying close attention to safety factors.

Fatigue design criteria fall into the following categories:

- Infinite life design
- Safe life design
- Fail-safe design
- Damage tolerance design

An almost linear relationship exists between austentite content and fracture toughness of ductile iron castings; similarly, fracture toughness is a function of silicon content. Moreover, structural inhomogeneities, such as segregation and degenerated graphite, influence fracture toughness values significantly, as will nodule distance. In general, the value of K_{cl} has been observed to increase with testing temperature, but much more fundamental information is required. ❍

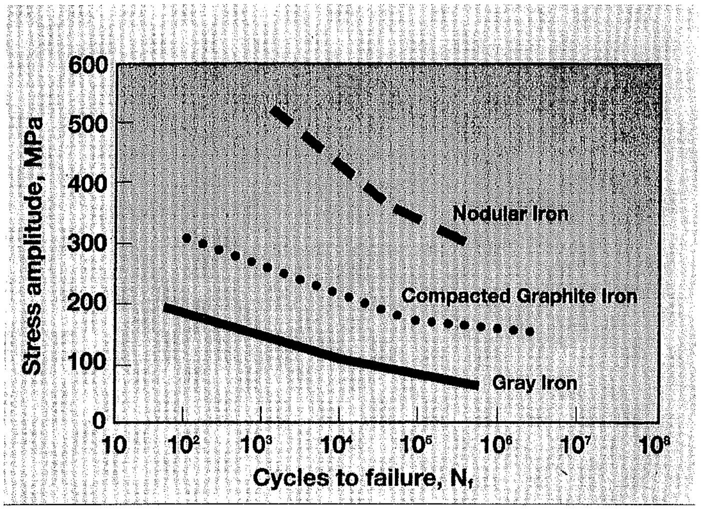

Figure 2. Comparison of typical strain-life fatigue curves or nodular (ductile), gray, and compacted graphite cast irons.