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Macroshrinkage and mold height correlation for gery cast iron casting

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ABSTRACT:

Macro shrinkage results, due to the interaction of several complex influences in iron. The grating, risering, and the iron chemistry needs to revised, when the shrinkage is constantly present in cast products on a regular basis. It has been observed that the problem of macro shrinkage is within the control and timing of the graphitizing process, when it occurs irregularly and the iron chemistry is consistent during the episodes of shrinkage.

It is necessary to maximize the formation of late graphite, without having to reduce the actual amount of graphite, in an effort to minimize the problem of macro shrinkage in cast products.

KEY WORDS – *S.G. Iron, grey cast iron, wooden cylindrical pattern*

I. INTRODUCTION

Grey and ductile irons have very different solidification characteristics with gray iron having minimum shrinkage issues and ductile iron constantly having shrinkage issues. This month we will examine what makes the difference and what you can do to about it.

Gray Iron typically runs 3.2 to 3.4 percent carbons while ductile are more typically 3.6 to 3.8 percent carbons. The end results are also a little different. Gray iron typically is pearlitic while ductile can be ferritic, 40-50% pearlitic, 80% pearlitic or even 100% pearlitic. So since 100% pearlite requires 0.8% carbon, there is that much less graphite to counteract shrinkage. Let me explain.

Graphite density ranges from 2.09 to 2.23 and iron density is 7.874 so 1 gram of graphite has the same volume as 3.53 grams of iron for high density graphite to 3.77 grams of iron for low density graphite.

A 100 gram casting of iron will shrink 10% or 10 grams volume on cooling to room temperature. That volume loss could be replaced by 2.65 to 2.83 grams of graphite or 2.65% C to 2.83% C depending on the density of the graphite. Assuming high density graphite, 2.83% carbon as graphite + 0.8% carbon as pearlite gives us a total of 3.83% C. Low density graphite gives 2.65% carbon as graphite + 0.8% carbon as pearlite = 3.45% carbon to produce shrink free gray iron.

Assuming an average gray iron value of 3.3% carbon leaves us with a shortage of 0.15% C to 0.53% C which then equates to a volume loss of 0.57% to 1.87% actual shrinkage. This shrinkage occurs in three stages: liquid cooling, liquid to solid transformation, and solid cooling. The liquid cooling is generally made up by risers or a well-designed gating system and the solid state cooling shrinks the entire casting the same amount so there is no concentration of shrinkage to form internal porosity. It is the Liquid to solid transformation that we generally have to worry about.

One of the key points of gray iron is that the graphite forms during the liquid to solid transformation with some graphite flakes actually growing from the solid metal out into the liquid. The shrinkage can then go into four different places: smaller dimensions, actual micro-porosity, less dense graphite, and grain boundary disorder (stress). Since gray iron is hypoeutectic, strong walls quickly form so only in slow cooling areas (sharp fillets and hot spots) is there an actual chance ofdimensional change or suck-in. These can usually be resolved by chills or redesign of the casting [1, 2].

The energy to form less dense graphite, or even disordered grain boundaries is considerably less than the energy required to form an interior surface or a shrinkage void. So the casting tries to hide its lost volume into these features first before actually forming shrinkage. Thus we generally find stubborn gray iron shrinkage only in unfed heavy sections. Ductile iron is different in that the graphite grows later. Whereas in Grey iron, the graphite growth is faster than the phase diagram suggests (level rule), in ductile iron, it is slower than the phase diagram suggests. Magnesium inhibits the formation of graphite, so it generally doesn't form in the liquid below 4.6 C.E. And even at the end of solidification (solidus), much of the graphite to be is still in the austenitic iron matrix. By my estimates, at solidus, only 50 to 60% of the total final graphite has formed. This causes a problem in the casting. Without the volume growth of graphite, the casting has a volume deficit that can push the casting over into actual shrinkagedimensional change or suck-in. These can usually be resolved by chills or redesign of the casting [3, 4].

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Macro shrinkage: - Macro shrinkage is a phenomenon associated with metal casting process. Macro shrinkage occurs, when the liquid metal is surrounded by significant amount of solid material, which is strong enough to resist the depression of the contracting liquid. The phenomenon of macro shrinkage occurs as a concentrated zone of shrinkage holes or single shrinkage cavity in cast products that can be detected through non-destructive tests, such as radiography, ultrasound, and magnetic particle method. The non-destructive tests and techniques help in eliminating the problem of macro shrinkage in cast products and improve their quality [5].

II. SHRINKAGE

A 100 gram casting of ductile iron will shrink 10% or 10 grams volume on cooling to room temperature. That volume loss could be replaced by 2.65 to 2.83 grams of graphite or 2.65% C to 2.83% C depending on the density of the graphite. Assuming high density graphite (worst possible case), 2.83% carbon as graphite + 0.8% carbon as pearlite gives us a total of 3.83% C. A ferritic casting would only require 2.83% carbon, well below the typical 3.6 to 3.8% typical carbon levels. So this logic would lead one to think that all of our ductile castings should be solid. Well obviously there is a problem: only about 60% of that graphite is present when the casting is finally solid. The rest grows as the casting cools down to the eutectoid temperature of about 1400 F (745 C – varies with chemistry composition). That means that our useable graphite is only 2.16 to 2.28% at solidus leaving us with a deficit of about ½ % volume. A 5 pound casting could have a shrinkage hole of about ¾ inch (1.9 cm) diameter if that volume deficit were to result in shrinkage.

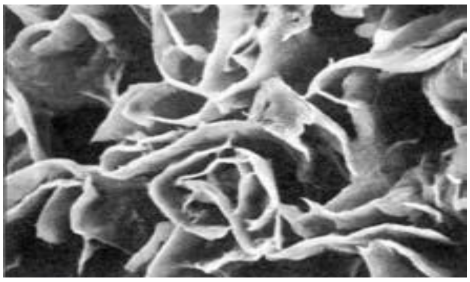
There are three things that can happen to that volume loss: it can be expressed as stress, suck-in or shrinkage. The idea casting will have it expressed as grain boundary stress because this stress will be eliminated by the later graphite growth. The suck-in and shrinkage voids don't get eliminated by the late graphite growth, but the casting may swell slightly. The trick then is to get the casting wall strength high enough to resist suck-in by eliminating hot spots, and then, somehow to avoid the concentration of stress in one area that would lead to the formation of an interior surface (a void). Higher stress is better, lower stress suggests that the stress has somehow been relieved though shrinkage or suck-in [6]. The following is a general discussion of the chemistry and gating of ductile iron and how it affects solidification.

Smaller size ductile iron is generally made close to eutectic composition of 4.3% C.E. This leads to a slow thickening of the walls, and the casting is slow to take on the strength necessary to resist shrinkage forces. But this also keeps the gating open as the gates are very slow to freeze off so good gating and risering can compensate and feed the casting though the first part of solidification whereas in gray and heavy section ductile, the hypoeutectic composition causes dendrites to quickly block off the gates. [1]

There is sometimes a problem with the chemistry of smaller ductile iron where increasing carbon starts causing more problems than it solves. Many foundries have found that C.E. can be increased beyond 4.3% and give beneficial results. They typically run 4.4 to 4.6% C.E. and get the added benefit of more graphite and better fluidity for thin section. The problem happens when the higher carbon starts forming graphite in the liquid. As of right now, I do not know if there is an inverse relationship between graphite formation and magnesium content. But I have seen liquidus graphite arrests in irons exceeding 4.6% C.E. This also shows up in micros as a strong bimodal distribution of nodules. The nodules growing in the graphite show up as the larger nodules. These early nodules are growing during the time the gates are still open, so their volume change pushes iron out of the casting cavity and back into the runner/riser system producing sound risers. Then, of course, when the casting freezes off, there is insufficient graphite forming during solidification and cooling and so the shrink that should have happened in the risers is transferred into the casting [2].

Mechanical Properties of Gray Cast Iron

1. Graphite morphology and matrixfig- 1, 2,Characteristics affect the physical and mechanical properties of gray cast iron. Large graphite flakes produce good dampening capacity, dimensional stability, resistance to thermal shock and ease of machining. While on the other hand, small flakes result in higher tensile strength, high modulus of elasticity, and resistance to crazing and smooth machined surfaces.



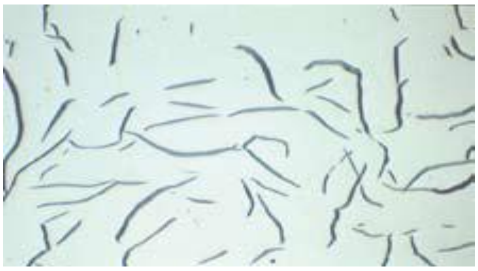


Fig-1 SEM image of grey iron with flake graphite Fig. 2: Well-polished graphite flakes

2. Mechanical Properties can also be controlled through heat treatment of the gray cast iron. For example as quenched gray cast iron is brittle [7]. If tempering is accomplished after quenching, the strength and toughness can be improved, but hardness decreases. The tensile strength after tempering can be from 35-45% greater than the as-cast strength and the toughness can approach the as-cast level.

III. MATERIALS AND EXPERIMENTAL PROCEDURE

Material: - 5kg of gray cast iron, 10kg of S.G. Iron, green, sand moulding box, wooden cylindrical pattern of height 17cm, 23cm, 25 cm.

Procedures:-

1. Make a wooden cylindrical pattern of diameter 3cm and heights of 17cm, 23cm, and 25cm.
2. Pattern is rammed in a mould box with green sand and pattern is removed
3. Gray cast iron, S.G. iron is melted in induction furnace to temperature 1200c.
4. Melted iron is poured in different mould boxes, cooled to room temperature, finally castings is removed out.
5. Cylindrical castings are cutted vertically downward symmetrically in machine shop. As shown in figures.
6. Sample taken for hardness testing and microstructure

IV. METALLOGRAPHIC PREPARATION

Cutting: White cast iron is very hard and therefore difficult to cut.

Grinding and polishing: Graphite is soft and retaining it in its true shape and size can be difficult. The matrix of ferritic and/or austenitic cast irons is prone to deformation and scratching Gray iron, or grey iron, is a type of cast iron that has agraphitic microstructure. It is named after the gray color of the fracture it forms, which is due to the presence of graphite. It is the most common cast iron and the most widely used cast material based on weight [8].

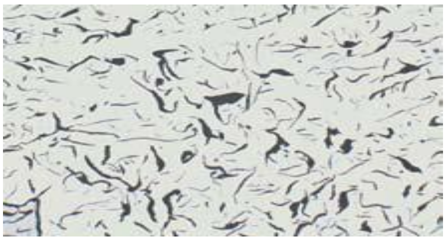


Fig.1: grey iron with flake graphite, 200 x insufficient polish

Fig. 2: showing correct polish 200x

It is used for housings where tensile strength is non-critical, such as internal combustion enginecylinder blocks, pump housings, valve bodies, electrical boxes, and decorative castings. Grey cast iron's high thermal conductivity and specific heat capacity are often exploited to make cast iron cookware and disc brake rotors [9].

Gray Cast Irons contain silicon, in addition to carbon, as a primary alloy. Amounts of manganese are also added to yield the desired microstructure. Generally the graphite exists in the form of flakes, which are surrounded by a-ferrite or Pearlite matrix. Most Gray Irons are hypoeutectic, meaning they have carbon equivalence (C.E.) of less than 4.3.

Fig 1. Gray cast irons are comparatively weak and brittle in tension due to its microstructure; the graphite flakes have tips which serve as points of stress concentration. Strength and ductility are much higher under compression loads.

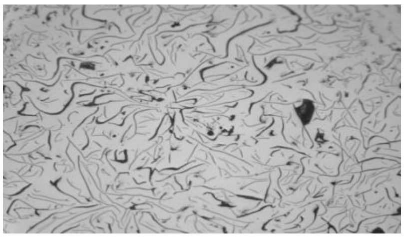


Fig.3. Microstructure of Gray iron under a 100x microscope

Fig 3a.Gray surface after fracture Fig. 3b Grey iron with flake graphite in 200x pearlitic matrix

V. RESULT AND DISCUSSION

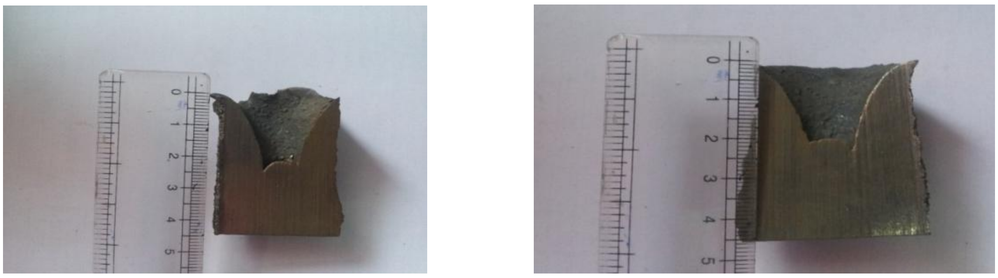
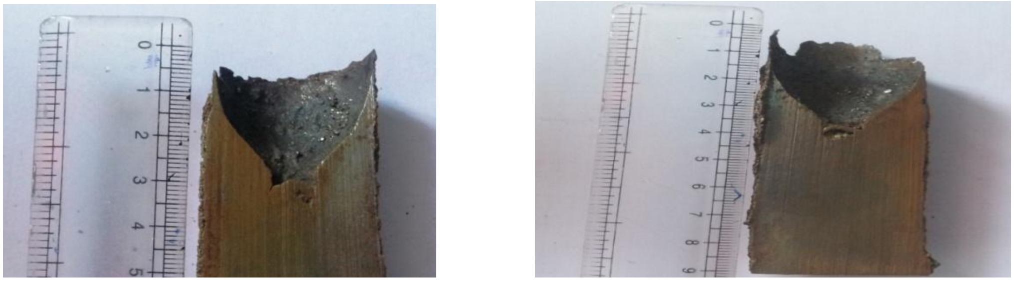


Fig. photographs of Macro shrinkage of gray cast ironcylindrical height 23 cm &17cm



S.G cast iron height 18cmS.G cast iron 27cm mould height

Mould height(h) of S.G iron	Shrinkage height(hs)	Mould height of gray cast iron	Shrinkage height (hs1)
17	4.2	17.2	4
22.5	3.7	18	2.4
23	5	20	0.5
23.5	3.6		
25	4.7		
27	*3.3*		

Measurments in cm, diameter is constant 3cm
Table 1- Hardness testing result for : - diameter of indentor 10mmGray cast iron, Load 3000 kg

	INDENTATION DIAMETER (cm)			B.H.N		
S.No	Point A	Point B	Point C	Point A	Point B	Point C
1	4.65	4.60	4.4	167	170	187
2	4.2	4.35	4.41	207	192	187

Table 2- Hardness result for S.G. Iron:- diameter of indentor 10mm, Load 3000kg

	Indentation diameter (cm)			B.H.N		
S.No.	Point A	Point B	Point C	Point A	Point B	Point C
1	4.4	4.45	4.5	187	183	179

Castings unfortunately can contain defects which may render them unsuitable for service, resulting in higher costs and/or lower profits for the production foundry and delivery delays to the customer. Some defects may not always be found prior to service - in fact, some *cannot* be found using normal non-destructive techniques - and there is always a danger that service stressing may cause a pre-existing defect to propagate, leading to premature failure.

VI. CONCLUSION

This lecture has provided an introduction to the nature and origin of major solidification defects in castings. Emphasis has been placed on how such defects can be diagnosed correctly and, more importantly, eliminated from the outset by using correct foundry techniques. Quality-conscious foundries are increasingly recognising that all parts of the production process must be properly controlled if the industry is to maintain its position of being a leading supplier of metallic components.

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