Commercial cast irons consist of many phases based on the iron-carbon-silicon system. These alloys usually contain impurity levels of certain reactive elements. The general conditions under which the eutectic liquid solidifies primarily determine the size and distribution of the graphite phase, which, in turn, is a major factor controlling mechanical properties. Addition of small amounts of magnesium and/or cerium to the technical cast iron melts during solidification causes graphite to form lamellae to spheroidal shape, leading to the well-known spherulitic cast iron or nodular cast iron or ductile iron.

Solidification of spherulitic cast iron is a process similar to the solidification of gray iron, except for considerable controversy over the forces that cause the nuclei of ductile iron to grow in a different crystallographic direction to obtain a different final morphology. Magnesium, which has a high affinity for sulfur and oxygen, forms stable compounds in addition to desulfurizing and refining effects on the melt. Subsequently, during the solidification of cast iron and the nucleation and growth of the graphite phase, free magnesium atoms are preferentially adsorbed by the growing graphite inclusions, producing spheroidization. Graphite spheroids initially grow directly from the melt in the direction of the graphite basal pole with the basal plane in contact with the liquid, but may be surrounded soon after formation by an austenite shell. Further growth occurs by diffusion of carbon atoms through the austenite shell [1].

The chemical analysis of the used material is: C = 3.24%; Mn = 0.27%; Si = 1.60%; P = 0.019%; S = 0.012% and Mg = 0.018%. Nital etched specimens were scanned [5, 6] in an optical microscope and photomicrographs to record the most important details are shown in Figs. 1 and 2. Fig. 1 is representative of the external section of the standard block. It is easy to see the graphite nodules surrounding the interfacial energy with the melt to a value below that of the basal plane [1]. When this occurs, the growth rate is along the prism pole [3] and a nodular morphology results. This change of the surface tension of the prismatic face of the graphite is due to high anisotropy of the graphite lattice [4]. However, kinetic effects play a key role in nodule formation. Then, it is possible to conclude that a high surface tension of the melt is indeed a necessary, but not sufficient, condition for nodular graphite formation [2]. Factors affecting graphite spherulite formation from the melt are summarized as: Chemical composition, Cooling Rate, Undercooling and Solidification Time. The former will be the only factor to be considered in present study because the complete thermal history of the Y-shaped ASTM standard block from the melt in the manufacture of castings is unknown.

The graphite nodule commonly observed in ductile iron is considered to be a perfect cluster of pyramidal grains with a common apex and the nodule-ferrite boundary will then be composed of basal planes of the hexagonal lattice. The spherulite in spite of this, has a high degree of crystallinity, which means, its carbon has a graphite crystal structure and there is no amorphous carbon present [2]. Some of the impurity atoms, the so-called subversive elements, can interfere with graphite shape formation. These elements influence the interfacial energies between graphite and the melt and also affect the kinetics of graphite morphology. The adsorption of foreign atoms onto the prism faces, reduces the interfacial energy with the melt to a value below that of the basal plane [1].
ded by ferrite envelopes; same time, we also see both appreciable amounts of degenerated and non-encapsulated graphite. Some spheroidal nodules with ragged exterior and non-uniformity in nodule size are displayed in this microstructure which shows 35% ferrite, 48% pearlite and 17% graphite. Of course, in commercial ductile irons nodule surfaces are not smooth but exhibit numerous protuberances as shown in the upper big spheroid of graphite. Incomplete graphite nodules are present in the lower left of this micrograph and incipient flake-nodule hybrids are seen in the lower left to right side. Fig. 2 [5], is typical of the interior of the standard block. Variety in the shape of the graphite aggregates, ranging between few amounts of both nodular and flake-nodule hybrid graphite, appreciable amounts of branched undercooled graphite and abundant non-encapsulated graphite in a ferrite-pearlite matrix. [6].

Graphite hybrids are due to undertreatment with magnesium [7], which is explained as follows: from the chemistry of our material we find that the amounts of silicon and manganese are very low; the minimum amount of required manganese to neutralize sulfur as MnS is 0.33%, then there exists a difference [6] of −0.06% Mn. This indicates the presence of free sulfur which will react with magnesium to produce MgS [8], reducing the nodularizer effect of magnesium. This sulfur evaporates magnesium due to the low vapor pressure of magnesium sulfide [4, 9]. Free sulfur comes back to the liquid as a powerful surface-active element [4, 9] easily segregated onto the graphite crystallographic planes of higher interfacial graphite-melt energy [10]. This in turn produces a decrease of the surface energy of prismatic surfaces [3, 4, 9-11], and leads to the change of morphology from initially nodular to laminar graphite.

The extremely low amount of silicon indicates [10] a very poor post-inoculation treatment effect, probably due to very low post-spheroidal graphite growth. Breakdown of graphite lamellae is typical of low sulfur iron melts. Coarsening of graphite is due to the undercooling lowering effect of sulfur [12].

The presence of non-encapsulated graphite indicates the existence of trace elements which can prevent envelope formation. These trace elements enrich the graphite-matrix interface, modifying the atomic attachment kinetics of carbon onto graphite [13]. These elements are segregated in a thin layer of the interface boundaries where they prevent the nodules acting as carbon sinks [14]. The resulting microsegregation is due to [15] the limited extend dissolution in the matrix, even at very low trace elements concentration.

REFERENCES