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HIGH PERFORMANCE CAST IRON MATRIX COMPOSITE - SOLIDIFICATION PATTERN CONTROL BY THERMAL ANALYSIS

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ABSTRACT

The routine measurements of metallurgical treatments effects in a foundry are in many ways empirical and have to be calibrated as well as interpreted to have any value in managing the process. It is well known that "analysis" results from a spectrometer sometimes do not reflect the truth or match other benchmark test values. With the more widespread adoption of thermal analysis testing, thermal analysis data have become an indicator of iron quality. Selected representative results are presented, as effects of some important technological factors, such as superheating in acid lined, induction furnace, thermal properties of mould media and solidification cooling rate.

Keywords: high performance cast iron, termal analysis, metal matrix composite.

INTRODUCTION

Cast iron is more than 70% of the total world metal casting production [more than 70 millions tons castings each year], with a great development potential. This material is especially attractive to the automotive industry, because of its excellent properties such as castability, machinability, heat conductivity and vibration damping capacity, at low cost production. Thin walls irons castings [less than 5mm wall thickness] are more and more attractive in this field. Ductile iron is also the material of choice for many of the world major wind turbine manufacturers. The need to ensure optimum, consistent and safe performance of these units makes it imperative that only ductile iron castings of the highest integrity and in complete compliance with the specification can be accepted, especially as requirements for high impact properties in ductile iron at low temperatures.

Industrial cast iron is a multi-element [more than 30 elements usually presence] eutectic alloy. The crystallization conditions are significantly different from that of equilibrium phase diagram measured at very slow cooling rate, using very pure materials, under vacuum melting, etc. Non-equilibrium solidification conditions, typically for iron castings in foundry industry, favour stable to metastable system crystallization transition, austenitic dendrites formation also in eutectic-hypereutectic chemical composition ranges, elements segregation, different eutectic solidification undercooling [up to 50^0C or more], etc.

Commercial cast iron is a typical multi-phase, natural metal matrix composite, including a ferrous matrix at different alloying grade and several phases, each having varying levels of carbon and other elements present, such as carbide, graphite, nitride, etc. Cementite has the highest hardness (~660 HB), whilst graphite is a relatively soft, low density material, which can act as a lubricant. Hardness, machinability, strength, ductility, toughness, thermal properties of the as-cast structure are, therefore, influenced by the relative amounts of cementite and graphite. So, high efficiency metallurgical methods need to be investigated, to control solidification pattern of iron castings, especially in critical solidification conditions.

Graphite nucleation sites formation as size, distribution and morphology and their growth pattern to obtain different final graphite morphologies (lamellar/flake, vermicular/compacted or nodular/spheroidal) could be influenced by modification and/or inoculation treatments. Higher graphite particles compactness degree [from lamellar through compacted up to spheroidal form], lower their capacity for stress concentration, and as result, higher all of the mechanical properties level, especially ductility. Inoculation is a graphitizing treatment of the molten iron, applied to all of cast irons, in order to obtain an as-cast structure without carbides and with high quality graphite shape (the best expected graphite morphology specifically for each cast iron type).

RESULTS AND CONCLUSIONS

It was found that some active elements, such as sulphur, oxygen, aluminium, calcium, magnesium, rare earth are important to control in-situ carbide / graphite phase formation in cast iron matrix composite material, a major purpose of the present paper was to investigate the solidification pattern and structure of cast irons, with intentionally critical conditions for graphite nucleation, typical for electric melted iron, by thermal analysis technique; this is especially pertinent to the production of thin section iron castings.

Increased chill correlates well with certain thermal analysis parameters, such as the degree of eutectic undercooling, referring to the both stable (graphitic) and metastable (white) eutectic temperature. Using the elements Al and Zr to precondition the molten base iron before tapping led to improved solidification parameters as measured by the most significant thermal analysis cooling curve events, in both untreated and inoculated irons. A double treatment incorporating preconditioning with inoculation improved the thermal analysis parameters, and consequently, the quality of the grey iron.

A good relationship between the power of inoculants to decrease the eutectic undercooling during solidification and their efficiency in reducing the amount of free carbides was found, but also depending on the solidification cooling rate. It was found a beneficial effect of a complementary addition of an inoculant enhancer alloy [S, O and oxy-sulphides forming elements] with the conventional Ca-FeSi alloy, in the production of grey and ductile irons, with higher solidification cooling rates, even though the total enhancer addition is only a small fraction of the amount of commercial inoculant used [1:3 ratio typically]. The main focus was on the carbides forming tendency and the characteristics of the graphite phase, in comparison to Ca / Ca,Ba / Ca,RE-FeSi alloys, in an in-mould inoculation technique.

An experimental device was developed with a technique to simultaneously evaluate cooling curves and expansion or contraction of cast metals during solidification. Several key parameters were identified which correlate with the peculiar behavior of inoculants as relate to graphite evolution and shrinkage sensitivity of ductile iron. Undercooling at the end of solidification relative to the metastable (carbidic) equilibrium temperature and the expansion within the solidification sequence appear to have a strong influence on the susceptibility to macro - and micro - shrinkage in ductile iron castings. With higher maximum initial expansion (shortly before the end of eutectic solidification) and / or greater undercooling (more negative) at the end of solidification, there is an increase in concentrated and dispersed shrinkage volumes, which lowers the apparent density of ductile iron castings.