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A Novel Material used in Automotive Industry: Compacted Graphite Iron

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Abstracts

In recent decade materials have been a key to increase the performance of automotive parts which leads to development of new materials. Main objective is to achieve increase in quantity and quality of automotive parts produced and for an optimum performance along their life cycle. Cast iron has remained a competitive material due, in part, to its low production cost. In fact, among the cast iron group one of an alternative is lightweight alloys i.e. compacted graphite iron (CGI). Now-a-days, it is accepted that CGI can effectively reduce the total weight of an automobile by virtue of its high strength, when compared to other cast irons and aluminum alloys. The paper gives a comparative view of CGI with gray cast iron (GCI) & ductile iron (DI). Surface morphology studied by SEM micrograph. Tensile strength and other properties can be calculated by stress-strain curve. Hardness measured by Brinell hardness testing m/c. Several metallurgical variables need to be strictly controlled in order to achieve consistent CGI properties in a production line at reasonable costs for automotive industry with at least 75% higher tensile strength, 45% higher stiffness and approximately double the fatigue strength of conventional grey cast iron.

Key words: CGI; Automobile Equipments; Spheroidal structure; Magnesium.

1. Introduction

Compacted graphite iron (CGI) accepted as a demanding important material for automotive equipment because as a high strength iron it can help higher performance for which it continues to gain use within the automotive industry (I. Kiss et al., 2010, see www.enginetechnologyinternational.com). It is known that material share in a vehicle price is over ~50%. For example, the crankcase is the engine component with the largest single mass, contributing approximately 25% the overall engine weight, and thus representing the main potential for weight reduction. For that reason, automotive industry needs to reduce the weight of each automobile component and thus unit as a whole. In that, respect a great progress has been made in the development and application of stronger and lightweight materials. CGI has been known for many years, although more research has been carried out recently (Sun X. et al., 2007, Diandra L. P., 2009, Berglund A., 2011, Berglund A. et al., 2009, Wu Y. et al., 2009, Fukumasu N.K., et al. 2005). CGI also known as the name “Vermicular Graphite Cast Iron” because it appears as individual ‘worm-shaped’ or vermicular particles. The production of ingot moulds, slag pots and casting trays has for many years been in compacted graphite irons, although these are all thick section castings without the intricacy of automotive casting design. In recent times, cylinder blocks & heads , brake drums and discs, manifolds, turbochargers and even piston rings have been produced in compacted graphite irons (Dawson S., 2008, Imasogie B. I., 2003, Guesser W. et al., 2001, ‘see www.onemotoring.com’, ‘see www.sintercast.com’).

Typical ductile iron will have residual magnesium of 0.025-0.06% Mg, depending on the casting section thickness and the type of castings being made. The spheroidization of graphite in cast irons via small amounts of nodulizing elements (Mg, Ce and other rare earths) to the melt promotes a structural change in the formation of graphite. For compacted graphite irons, the residual magnesium tends to be in the range of 0.01-0.03% and standard MgFeSi alloys can be used. The formation of CGI is a very difficult process to control with only a narrow residual Mg, because too high Mg will give an excess of nodules while too low Mg will lead to the formation of grey iron flake structures.

2. Experimental Procedure

The base iron was melted in an electric arc furnace as part of the standard base iron for ductile iron production. Base treatment was performed with a commercially available MgFeSi alloy followed by SinterCast thermal analysis and the addition of corrective amounts of 5 mm magnesium and/or 9 mm diameter inoculant cored wires to obtain the desired CGI microstructure. The alloying content and optimum concentration of the nodularizing/modifying pre-alloy composite were chosen based on data from earlier work (Dawson S., 2001). The weight percentage of Mg in the masteralloy was varied and compacted into capsule-shaped briquettes. A heat of a base iron of composition (Fe-3.73C-0.98Si-0.10Mn-0.023S-0.054P-0.04Cr-0.20Cu-0.005Mg) was melted in an electric arc furnace, superheated to about 1600 °C, held for 5 min, and tapped at around 1490 °C onto a calculated amount of the treatment agent in a preheated treatment ladle and cast after graphitization inoculation with 0.5% $Fe_{75}Si$ (Fe-73.29Si-2.64Al), without reladling. The castings were produced in green sand moulds. The Standard test pieces were taken for microstructural testing. Composition was analyzed using both EDX and WDX spectroscopy. Information on graphite morphology, compactness and matrix features was obtained using a computer-based image analyzing system. A detailed assessment of structure (matrix features and graphite morphology) was made on samples from the broken impact test specimens, since these were representative of the structure of the sections used for the determination of the mechanical properties. Tensile tests for all specimens were carried out at a constant displacement rate of 0.05 mm/s by tensile testing machine equipped with autographic recording of the stress-strain curve, to allow determination of the 0.2% offset yield strength, as well as the tensile strength and elongation at failure. Notched Charpy impact tests at room temperature were carried out with a striking energy of 300 J. Following standard procedure, a series of Brinell micro-hardness measurements was conducted using appropriate accessories on and microscope.

3. Results and Discussion

3.1 SEM Micrograph of CGI:

In figure-1, Gray cast iron, compacted graphite iron and ductile iron are differentiated by the shape of the graphite particles. Gray iron is characterized by randomly oriented graphite flakes while in ductile iron the graphite particles are present as individual spheres. But in case of CGI, the graphite particles are appearing as individual worm-shaped or vermicular particles. The particles are elongated and randomly oriented as in gray iron, however they are shorter and thicker, and have rounded edges. While the compacted graphite particles appear worm-shaped and the individual 'worms' are connected to their nearest neighbors in a complex coral-like graphite morphology (shown in figure-2). Both of the rounded edges and irregular bumpy surfaces of the compacted graphite particles, the coral-like morphology results in strong adhesion between the graphite and the iron matrix (Guesser W. et al., 2001). While the smooth-surfaced graphite flakes in gray iron promote crack initiation and growth and thus render the material relatively weak and brittle, the entangled compacted graphite morphology eliminates the natural cleavage paths thus providing strength and stiffness.

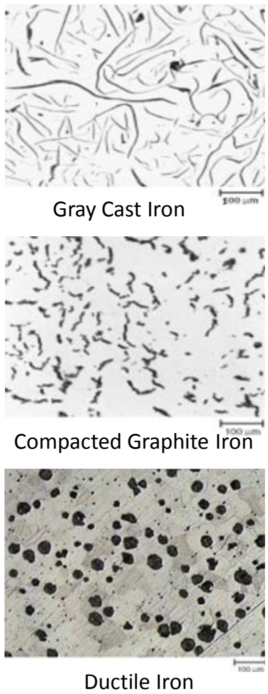

Figure 1: Gray iron, compacted graphite iron and ductile iron are differentiated by the shape of the graphite particles (100X magnification).

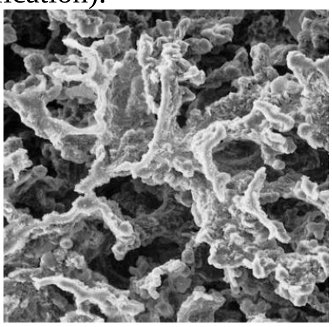

Figure 2: coral-like graphite morphology of CGI (250X magnification).

It was noted that the microstructures of the gray irons were very similar to each other, consisting basically of pearlite and flake graphite, the only difference being their graphite content. The CGI, however, presented also ferrite in its microstructure, besides pearlite, vermicular graphite and traces of spherical graphite. The $L/D = 4.8$ (L: length and D: width) average value of the graphite aspect ratio of the three gray irons shows that its morphologies are very similar, and clearly different from CGI which presents a L/D close to 3.

Figure-3 show the effect of magnesium content in the alloy. From plot it is clearly visible is that by increasing in weight percent of magnesium, the flakes are largely decreases.

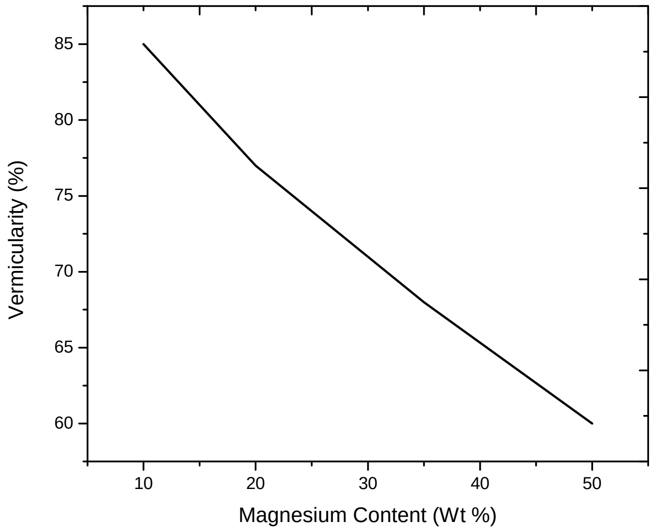

Figure 3: Effect of magnesium content on compacted graphite percentage.

3.2 Comparison of Mechanical Property of CGI with GCI and DI:

It is known that the size or weight of CGI is 15% lighter in compare to gray cast iron (see foundrygate.com), for which it is very interesting for automotive industry to find out its mechanical properties. By tensile test it was calculated the value of tensile strength, elastic modulus and elongation which are manipulated in figure-4 & -5. In Figure-4, experimental tensile strength and elastic modulus for GCI, CGI and DI are drawn. This figure indicates that the tensile strength of CGI is in between the lower value of GCI & higher value of DI. But in account of elastic modulus, the value for CGI is greater than GCI and about same as that of DI. Elongation property shown by the figure-5, in which it is clear that the elongation value of CGI is less than the DI and for GCI it is almost zero. From this value we can confirm that CGI can be used in higher working load equipment. In figure-6 hardness property (BHN value) is compared among CGI, GCI & DI. Here it is observed that, hardness of CGI is in between GCI & DI

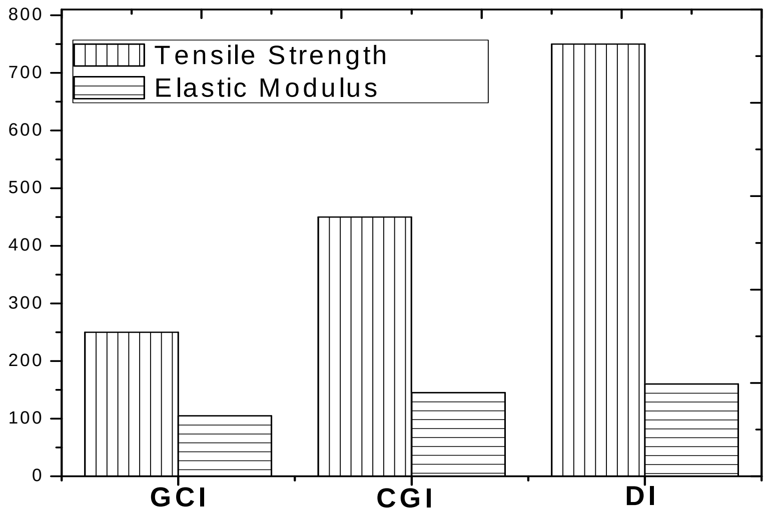

Figure 4: comparative graph of tensile strength & elastic modulus for GCI, CGI and DI.

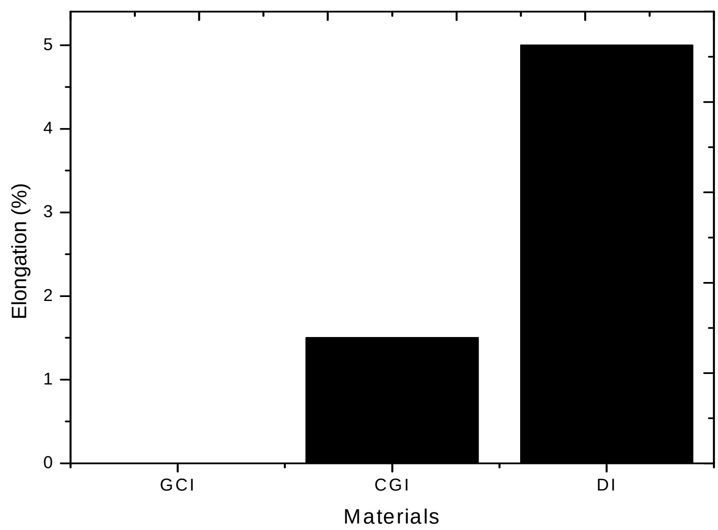

Figure 5: comparative graph of material elongation for GCI, CGI and DI.

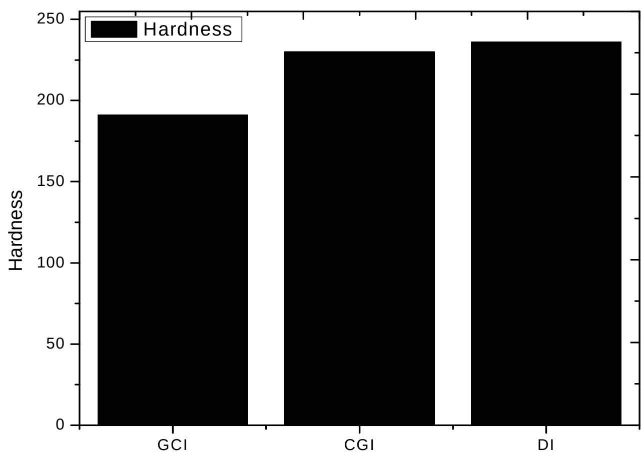

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Figure 6: comparative graph of hardness for GCI, CGI and DI.

4. Conclusions

The properties of compacted graphite iron relative to grey iron provide many opportunities for improved engine design and performance, both in passenger vehicles and commercial vehicles. By CGI, there is also improved in thermal & mechanical loads require with the performance; which leads to new design solutions. CGI is becoming more widespread in the commercial vehicle sector, which leads to developing additional CGI engines.

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