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Study on Heat Treatment of S.G Cast Iron and Its Effects

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ABSTRACT

S.G Cast iron is defined as a high carbon containing, iron based alloy in which the graphite is present in compact, spherical shapes rather than in the shape of flakes, the latter being typical of gray cast iron . As nodular or spheroidal graphite cast iron, sometimes referred to as ductile iron, constitutes a family of cast irons in which the graphite is present in a nodular or spheroidal form. The graphite nodules are small and constitute only small areas of weakness in a steel-like matrix. Because of this the mechanical properties of ductile irons related directly to the strength and ductility of the matrix present—as is the case of steels. One reason for the phenomenal growth in the use of Ductile Iron castings is the high ratio of performance to cost that they offer the designer and end user. This high value results from many factors, one of which is the control of microstructure and properties that can be achieved in the as- cast condition, enabling a high percentage of ferritic and pearlitic structure.

INTRODUCTION

After three hundred years of progress, the above words of Joseph Glanville are still true. Knowledge is certainly preferable to speculation. And yet, the approach towards solving a given practical problem will be confusing and haphazard without the guidance of ideas on at least what may take place during solidification. Willing or not, one must depend, in part, on hypotheses.

Developed in 1943, it was found that by adding magnesium before pouring caused the graphite to form nodules rather than flakes. This resulted in a new material, with excellent tensile strength and ductility.

Adding these mechanical properties of this material to the advantages already offered by cast iron soon led to it finding its way into virtually every mainstream area of engineering, in many cases replacing existing steel castings or forgings due to achievable cost savings. S.G Cast iron or Ductile Iron (DI) is an iron-carbon alloy having structure of nodules of graphite embedded in steel matrix. It derives its name as it has graphite in the form of spheroids embedded in the steel matrix, normally of ferritic, or pearlitic.

These nodules of graphite are formed directly from the liquid during the process of solidification. The nodules are more regular, sharp and compact sphere. The matrix of ductile irons can be varied from a soft and ductile ferritic structure, through harder and higher strength pearlitic structures to a hard, higher and comparatively tough tempered martensitic or bainitic structure. Thus, a wide range of combinations of strength and ductility can be achieved. General engineering grades of ductile iron commonly have the structures which are ferritic, ferritic/pearlitic or pearlitic. Controlled processing of the molten iron precipitates graphite as spheroids rather than flakes.

The round shape of the graphite eliminates the material's tendency to crack and helps prevent cracks from spreading. Control of matrix structure: The main trace elements present in ductile iron can have a marked influence on the structure and hence the properties of the iron With the exception of silicon, all elements promote pearlite and all elements with the exception of silicon, nickel and copper also promotes carbides. The strength properties of ferritic ductile iron are generally increased by the elements, which go in to the solution.

With the exception of carbon, all the elements increase tensile strength and hardness. An example of the extent to which ferrite is affected by solid solution strengthening is illustrated for the elements silicon and nickel.

A 1% addition of silicon raises the proof and tensile strength of a ferritic iron by approximately 82 N/mm2 whereas 1% of nickel increases these properties by 46 N/mm2. In the ferritic irons increase in tensile strength and proof strength are obtained at the expense of ductility and in such case the iron can become embrittled.

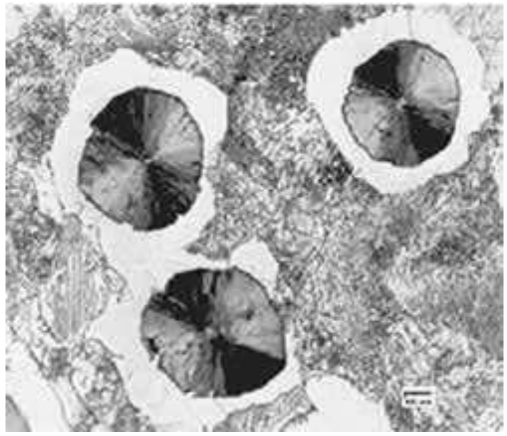

FIG. 1.1 The graphite in spheroidal form in the microstructure of S.G cast iron

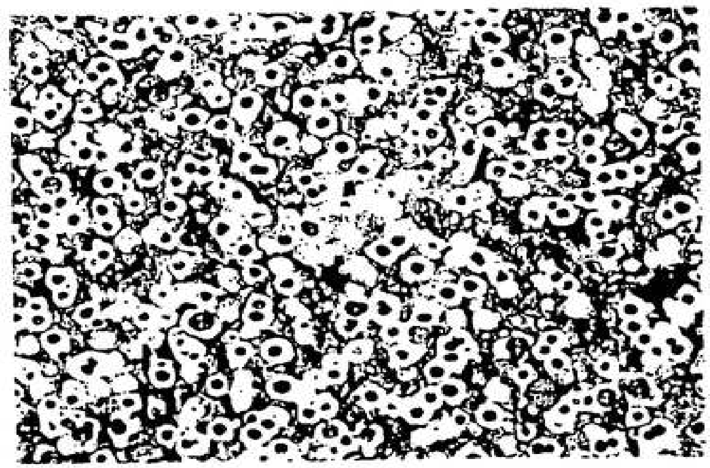

Fig.:1.2 The microstructure of S.G cast iron

LITERATURE REVIEW

Production of S.G Iron

Desulphurization: Sulphur helps to form graphite as flakes. Thus, the raw material for producing S.G Iron should have low sulphur (less than 0.1%), or remove sulphur from iron during melting, or by mixing iron with a desulphurising agent such as calcium carbide, or soda ash (sodium carbonate).

Nodulising: Magnesium is added to remove sulphur and oxygen still present in the liquid alloy and provides a residual 0.04% magnesium, which causes growth of graphite to be spheroidal, probably the interface energy becomes high to have a dihedral angle of 180 degree,(in simple term the graphite does not wet the liquid alloy.). Magnesium treatment desulphurises the iron to below 0.02% S, before alloying it. Magnesium and such elements have strong affinity for sulphur and thus scavenge sulphur from the molten alloy as an initial stage for producing S.G Iron. These additions are expensive to increase the cost of S.G Iron produced. Thus sulphur of molten alloy (or the raw material used), before nodulising, should be kept low.

Inoculation: As magnesium is carbide former, ferrosilicon is added immediately as inoculants. Remelting causes reversion to flake graphite due to loss of magnesium.

Average Composition of S.G. Cast Iron:
Carbon – 3.0 - 4.0 %
Silicon – 1.8 – 2.8 %
Manganese – 0.1 – 1.00 % Sulphur – 0.03% max.
Magnesium – 0.01 – 0.10 %

Properties of S.G Cast Iron

A number of properties such as mechanical, physical and service properties are of important in assessing materials suitably for any application. The mechanical properties of interest are tensile strength proof stress, elongation, hardness, impact strength, elastic modulus, and fatigue strength, notch sensitivity while the physical properties of interest are damping capacity, mach inability and conductivity. The service properties generally involved are wear resistance, heat resistance, corrosion resistance.

Properties
Easy to cast the high fluidity of the metal in its molten state makes it ideal for the casting process Strength Tensile strengths of up to 900N/mm2 (ADI gives the option of higher strengths).

Ductility Elongations of in excess of 20% (Lower grades only) Excellent Corrosion Resistance when compared to other ferrous metals. Ease of Machining Free graphite in the structure also lends itself to machining (chip formation).

Cost per Unit Strength Significantly cheaper than most materials Research work has shown that on a laboratory scale additions of a number of elements are capable of producing spheroidal graphite structures in the cast irons. These elements include magnesium, cerium, calcium and yttrium. However, owing to a number of factors the application of these elements on a production scale has been restricted to the element magnesium, although it is claimed that in Japan calcium based alloys are used for producing ductile iron castings. It is generally supposed that magnesium removes impurities such as Sulphur and oxygen, which may tend to segregate to free surfaces of molten metal, thereby lowering surface tension.

Similarly, these impurities lower the interfacial tension between the graphite and metal. When they are removed, this interfacial tension rises to a higher value and it is often presumed that it constrains the graphite to reduce its surface area per unit volume, which it does by assuming a spherical shape. The use of cerium results in nodular graphite structures, with certain type of metal compositions, but these restrictions and the general inconsistency of the process again makes it unsuitable for large-scale application. However, the benefits of including a small amount of cerium in the nodular sing process in order to offset the subversive nature of contaminating elements such as lead, antimony and titanium are well known, and the majority of ductile iron is produced using the cerium- bearing magnesium alloys.

METHODOLOGY

The experimental procedure for the project work can be listed as:

1. Specimen preparation
2. Heat treatment
3. Harden measurement
4. Mechanical property study
5. Microstructure study

Specimen Preparation:
The first and foremost job for the experiment is the specimen preparation. The specimen size should be compatible to the machine specifications:

We got the sample from L&T Kansbal. The sample that we got was GGG-50 S.G Cast iron.

Introduction of GGG-50 S.G Cast iron: It is one of the German standard (DIN) specifications of the ductile iron having the pearlitic matrix (up to 70%) with relatively less amount of ferrite (30-40%). And so it has high hardness with moderate ductility and high strength as specified below. So we can also say that it is basically a pearlitic/ferritic ductile iron.

The sample that we got was cuboidal rod of length 130 mm and thickness of around 40 mm. According to the ASTM standards for a specimen the ratio of gauge diameter to gauge length should be 1:5. Hence we went for a turning operation of the 14 samples that we got which we did in the central workshop. After the turning operation, the cuboidal rod was converted to a tumbler shaped specimen of the following specifications:

1. Gauge length – 70 mm
2. Gauge diameter- 14 mm
3. Total length- 90 mm
4. Grip diameter- 20 mm

Next the sample was subjected to various heat treatment processes and was taken to a UTS machine for testing of various mechanical properties.

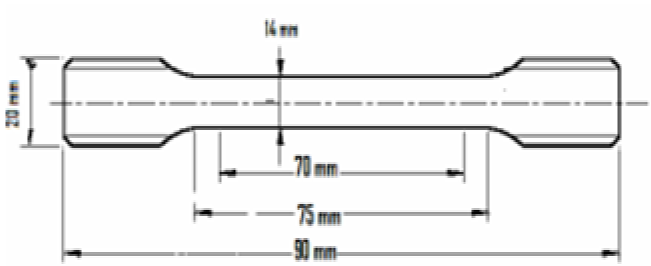

Fig. 3.1 Schematic diagram of tensile testing specimen

Heat Treatment

Nodular cast irons (or ductile, or spheroidal graphite iron) are primarily heat treated to create matrix microstructures and associated mechanical properties not readily obtained in the as-cast condition. As-cast matrix microstructures usually consist of ferrite or pearlite or combinations of both, depending on cast section size and/or alloy composition.

The principle objective of the project is to carry out the heat treatment of SG cast Iron and then to compare the mechanical properties. There are various types of heat treatment processes we had adopted.

Annealing

a) The specimen was heated to a temperature of 900 deg Celsius
b) At 900 deg Celsius the specimen was held for 2 hour
c) Then the furnace was switched off so that the specimen temperature will decrease with the same rate as that of the furnace

The objective of keeping the specimen at 900 deg Celsius for 2 hrs is to homogenize the specimen. The temperature 900 deg Celsius lies above Ac1 temperature. So that the specimen at that temperature gets sufficient time to get properly homogenized. The specimen was taken out of the furnace after 2 days when the furnace temperature had already reached the room temperature

Normalizing

a) At the very beginning the specimen was heated to the temperature of 900 deg Celsius
b) There the specimen was kept for 2 hour
c) Then the furnace was switched off and the specimen was taken out.
d) Now the specimen is allowed to cool in the ordinary environment. i.e. the specimen is air cooled to room temperature.

The process of air cooling of specimen heated above Ac1 is called normalizing.

Quenching

This experiment was performed to harden the cast iron. The process involved putting the red hot cast iron directly in to a liquid medium.

a) The specimen was heated to the temp of around 900 deg Celsius and were allowed to homogenize at that temp for 2 hour.
b) An oil bath was maintained at a constant temperature in which the specimen had to be put.
c) After 2 hour the specimen was taken out of the furnace and directly quenched in the oil bath.
d) After around half an hour the specimen was taken out of the bath and cleaned properly.
e) Now the specimen attains the liquid bath temp within few minutes. But the rate of cooling is very fast because the liquid doesn't release heat readily.

Tempering

This is the one of the important experiment carried out with the objective of the experiment being to induce some amount of softness in the material by heating to a moderate temperature range.

a) First the '9' specimen were heated to 900 deg Celsius for 2 hour and then quenched in the oil bath maintained at room temp.
b) Among the 9 specimen 3 were heated to 250 deg Celsius. But for different time period of 1 hour, 1and half hour and 2 hour respectively.
c) Now 3 more specimens were heated to 450 deg Celsius and for the time period of 1 hour, 1and a half hour and 2 hour respectively.

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Austempering

This is the most important experiment carried out for the project work. The objective was to develop all round property in the material

a) The specimen was heated to the temperature of 900 degree Celsius and sufficient time was allowed at that temperature, so that the specimen got properly homogenized.
b) A salt bath was prepared by taking 50% NaN03 and 50 % KnO3 salt mixture. The objective behind using NaNO3 and KNO3 is though the individual melting points are high the mixture of them in the bath with 1:1 properties from an eutectic mixture this eutectic reaction brings down the melting point of the mixture to 290 deg Celsius. The salt remains in the liquid state in the temp range of 290-550 deg Celsius whereas the salt bath needed for the experiment should be at molten state at 350 deg Celsius
c) After the specimen getting properly homogenized it was taken out of the furnace and put in another furnace where the container with the salt mixture was kept at 350d deg Celsius.
d) At that temp of 350 degree the specimen was held for 2 hrs In this time the austenite gets converted to bainite. The objective behind choosing the temperature of 350 deg Celsius is that at this temperature will give upper bainite which has fine grains so that the properties developed in the materials are excellent.

CONCLUSION

From the various results obtained during the project work it can be concluded that the mechanical properties vary depending upon the various heat treatment processes. Hence depending upon the properties and applications required we should go for a suitable heat treatment processes. When ductility is the only criteria tempering at high temperature for 2 hours gives the best result among all tempering experiments however it is simply the hardness of the S.G Cast iron that is desired than we should go for low temperature tempering for 1 hour or so. However if strength is also desired along with hardness, this should not be done. It is seen that annealing causes a tremendous increase in % elongation (ductility). It can be clearly seen comparing all the heat treatment processes, optimum combination of UTS, Yield Strength, % Elongation as well as hardness can be obtained through austempering only

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