ABSTRACT

The effect of minor additions of Sodium chloride (NaCl), Hexachloroethane (C_2Cl_6) and elemental sulphur (S) on solidification and graphitisation characteristics of white cast iron has been investigated.

Experimental white iron melts (carbon equivalent 2.8 - 3.0) were prepared in induction furnaces in the laboratory as well as in two local foundries. Mottle pins and tensile test pieces were cast in the two foundries from melts treated with either sodium chloride, hexachloroethane or sulphur. A few automobile components were also cast from melts treated with 0.1 - 0.2% NaCl in one of the foundries. The effect of the additives on solidification of white cast iron was assessed from the final microstructure of the mottle pins.

The progress of graphitisation in the laboratory samples during normal annealing at 950°C and during subcritical annealing at 700°C was examined using metallographic techniques. The kinetics of first stage graphitisation in commercial white iron samples was investigated by dilatometry. The dilatometer samples were machined from tensile test pieces. Tensile strength and ductility in both treated and untreated test pieces were determined after annealing the test pieces in industrial furnaces. Graphite morphology and fracture

characteristics in annealed samples were investigated by scanning electron microscopy. A few as cast and annealed NaCl treated samples were examined in ESCA. X-ray powder patterns and resistivity data of a few as cast untreated and NaCl treated samples were also obtained. Sulphur treated as cast and annealed samples were examined in an electron microprobe analyser. Test castings of automobile components were annealed and microstructure in the different sections were examined to evaluate the effectiveness of melt treatment with NaCl. The principal findings of the investigation are summarised below.

A) Effect of NaCl and C_2Cl_6 addition on solidification

Addition of NaCl and C_2Cl_6 to white iron melts exerts a chilling effect during solidification. The chilling effect is believed to be due to kinetic undercooling caused by traces of chlorine dissolved in the melt.

B) Effect of NaCl addition on first stage graphitisation in white iron samples prepared in the laboratory

It has been observed that first stage graphitisation in white cast iron is accelerated by addition of 0.05 - 0.1% NaCl to the melt. The carbide stabilising effect of residual chromium may therefore be partially neutralised by optimum NaCl addition to the melt.

C) Subcritical annealing of white cast iron

The present investigation has confirmed that graphite nucleation occurs during subcritical annealing of white cast iron and it is possible to produce ferritic malleable iron in one stage at 700°C within 60-96 hours. The general sequence of transformations occuring during subcritical annealing have been identified. The kinetics of graphitisation during subcritical annealing has been measured by quantitative metallographic technique and it has been found that the rate of graphitisation is strongly influenced by minor additions of sodium chloride to the melt just before casting and it is mildly influenced by the furnace atmosphere.

D) Effect of NaCl, C_2Cl_6 and elemental sulphur addition on first stage graphitisation kinetics in commercial white cast iron

Minor additions of NaCl, C_2Cl_6 and sulphur have been found to accelerate first stage graphitisation in commercial white cast iron. NaCl addition was made to both low manganese ($\approx$ 0.4) and high manganese ($\approx$ 0.85) commercial white cast iron. Hexachloroethane and sulphur additions were made only to high manganese white iron melts. On kinetic treatment of dilatometric data, the graphitisation process in the experimental alloys have been found to be carbon diffusion controlled. NaCl. C_2Cl_6 and sulphur treatments also reduce the activation energy for first stage graphitisation in white cast iron. Optimum dose of NaCl and C_2Cl_6 addition for accelerated graphitisation has been found to be around 0.1%. While traces of free graphite present in as cast state may act as ready substrates for graphite precipitation during annealing and thus reduce f.s.g. time, it is unlikely that this is the principal factor responsible for acceleration of malleablising anneal in the NaCl or C_2Cl_6 treated samples. Presence of traces of dissolved chlorine has been detected in the NaCl treated samples in ESCA. Presence of sodium has not been detected. It is likely that traces of chlorine present in NaCl or C_2Cl_6 treated samples influence graphitisation kinetics in a subtle manner, one of the possibility being enhancement of carbon diffusion in austenite through some mechanism which is not well understood at this stage.

E) Industrial trials

Tensile strength, yield strength and ductility of blackheart and pearlitic malleable iron tensile test pieces cast from melts treated with NaCl or C_2Cl_6 and annealed in industrial continuous annealing furnaces have been found to be comparable to those of untreated test bars. However, sulphur treatment causes a slight deterioration in mechanical properties. NaCl treatment also prevents mottling in thick sections (44 mm) of automobile rear axle housing castings. The optimum dose of NaCl addition depends upon the size of the melt to be treated, casting section size and the time lag between treatment and pouring. Usually the optimum is between 0.1 - 0.15%.

F) Graphite configuration and fracture in malleable iron

Examination in SEM has revealed that graphite nucleation in both treated and untreated samples occurs on pores created by shrinkage or by entrapped gases or both at austenite-carbide interface. Fully grown nodules in both treated and untreated samples have been found to be porous. The apparent volume of graphite in annealed white iron is, therefore greater than the volume expected from calculations based on chemical composition of white iron and true density of graphite.

Fracture characteristics of ferritic and pearlitic malleable iron has been examined in S.E.M. Ferritic malleable iron fails in a ductile manner under tensile stress. Unlike that in ferritic s.g. iron, the nodules in ferritic malleable iron are also fractured. Pearlitic malleable iron fails in a brittle manner.