The effects of vanadium in ductile (SG) cast irons

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Synopsis—The effects of up to 0.5 per cent vanadium in as-cast and annealed ductile cast irons have been examined. Vanadium increases the tendency for eutectic carbide and pearlite to occur in as-cast irons, but these are readily removed by a normal ferritizing heat treatment.

Vanadium produces some improvement in the as-cast tensile properties, but greater improvements occur when the irons are annealed to the fully ferritic condition.

Combined additions of vanadium and nickel in annealed ferritic ductile iron produce greater increases in tensile properties than other combinations of strengthening elements, with less decrease in ductility and less increase in the impact transition temperature. However, vanadium does not increase the creep resistance of these irons, and the fatigue limit is increased by no more than would be expected from the increase in tensile strength.

The effects of vanadium are attributed at least in part to the refinement of the ferrite grains and the formation of a fine, dot-like precipitate by the vanadium.

Introduction—Vanadium is an element that is rarely used in cast irons because of its strong tendency to promote the formation of eutectic carbide or 'chill'.

Recent work by the author[1] confirmed the increased chilling tendency in grey irons, but it also showed that, at vanadium levels below 0·5 per cent, the increased chilling tendency could be controlled by efficient inoculation. This resulted in potentially useful increases in tensile strength.

Only a small amount of work [2–5] has been published on the effects of vanadium in ductile irons, but this work and analogy with grey irons has suggested that vanadium is undesirable in ductile irons because of its tendency to promote the formation of eutectic carbide and pearlite.

Preliminary work at BCIRA confirmed that vanadium increases the tendency for eutectic carbide to form in ductile irons but its effect on the amount of pearlite formed was fairly slight. At vanadium contents below about 0·5 per cent, efficient ladle inoculation confined the carbide to the thinnest sections. Furthermore, it was found that any eutectic carbide formed was readily removed by the normal heat treatments applied to many ductile irons, such as normalizing or a ferritizing anneal. In this respect, vanadium differs from chromium which tends to produce eutectic carbide that is resistant to removal by heat treatment.

The tests also indicated that vanadium might produce some unusual and potentially useful effects on the structure and properties of some ductile irons. An extensive investigation has been carried out to examine these effects. The details of both the preliminary tests and the extensive investigation are given in this paper.

Production of the irons

All of the irons tested were produced in the BCIRA experimental foundry. The charges were based on high-purity oxygen-blown pig-iron and appropriate ferro-alloys and were melted in acid-lined medium-frequency induction furnaces. Vanadium was added as ferrovanadium, either to the melt in the furnace or to the stream of metal as it was tapped from the furnace and collected in the ladle. The alloys readily dissolved, and yields well in excess of 90 per cent were generally obtained.

The molten iron was poured at about 1420 °C onto 2·5 per cent of a 5%-magnesium/ferrosilicon alloy to obtain nodular graphite structures and was then inoculated with 0·35 to 0·5 per cent silicon as ferrosilicon. Test castings were poured between 45 seconds and 1 minute after inoculation.

Preliminary tests

Melts 1 & 2 were carried out to produce irons having a nominal final composition of 3·5 per cent carbon, 2·5 per cent silicon, 0·3 per cent manganese and 0·04 per cent

Table 1 Composition of Melts 1 & 2.

Melt & Tap No.	TC %	Si %	Mn %	S %	Mg %	V %	Ni %	Cr %	Cu %	Mo %	Al %	Sn %	As %	B %	Ti %
1/1	3·53	2·52	0·22	0·011	0·046	0·02	0·11	0·01	0·02	0·01	0·023	0·01	0·01	0·001	0·01
1/2	3·52	2·50	0·22	0·012	0·032	0·12									
1/3	3·51	2·47	0·22	0·011	0·041	0·24									
1/4	3·46	2·47	0·22	0·011	0·042	0·52									
2/1	3·56	2·52	0·31	0·011	0·035	0·03	0·08	0·01	0·10	0·01	0·025	0·043	0·018	0·001	0·01
2/2	3·54	2·51	0·31	0·010	0·037	0·12									
2/3	3·49	2·51	0·31	0·009	0·030	0·24									
2/4	3·46	2·47	0·31	0·009	0·043	0·51									