Compacted Graphite Iron – Material Data Sheet

Compacted Graphite Iron

The graphite particles in Compacted Graphite Iron (CGI) appear as individual 'worm-shaped' or vermicular particles. The particles are elongated and randomly oriented as in grey iron; however, they are shorter and thicker than the graphite flakes in grey iron, and have rounded edges. While the compacted graphite particles appear worm-shaped (vermicular) when viewed in two dimensions, deep-etched SEM micrographs show that the individual 'worms' are connected to their nearest neighbours within the eutectic cell. This complex coral-like graphite morphology, together with the rounded edges and irregular bumpy surfaces, results in strong adhesion between the graphite and the iron matrix. This compacted graphite morphology inhibits crack initiation and growth and is the source of the improved mechanical properties relative to grey iron.

The ISO 16112:2017 international standard for CGI provides for five grades of CGI, ranging from a minimum tensile strength of 300 MPa to 500 MPa (GJV 300 to GJV 500). For each of these grades, the microstructure specification requires a nodularity range of 0–20%. Pearlite content can be chosen to suit the application, with the GJV 300 Grade being fully ferritic and the GJV 500 Grade being fully pearlitic. Flake graphite is inadmissible. As with grey iron and ductile iron, specific alloying elements can be added to enhance high temperature strength, wear resistance or other properties. A full range of heat treatments, including austempering, can also be applied. Typical chemistry ranges are provided below, although the chemical specification of CGI castings is subordinate to mechanical properties.

Typical Chemistry Ranges for 0–20% Nodularity CGI

Grade	Pearlite (%)	Chemical Analysis (%)								
		C	Si	CE	Mn	S	Mg	CeMM	Cu	Sn
GJV 400	~ 70	3.6–3.8	2.1–2.5	4.4–4.7	0.2–0.4	0.005–0.022	0.006–0.014	0.01–0.03	0.3–0.6	0.03–0.05
GJV 450	> 90	3.6–3.8	2.1–2.5	4.4–4.7	0.2–0.4	0.005–0.022	0.006–0.014	0.01–0.03	0.7–1.0	0.08–0.10

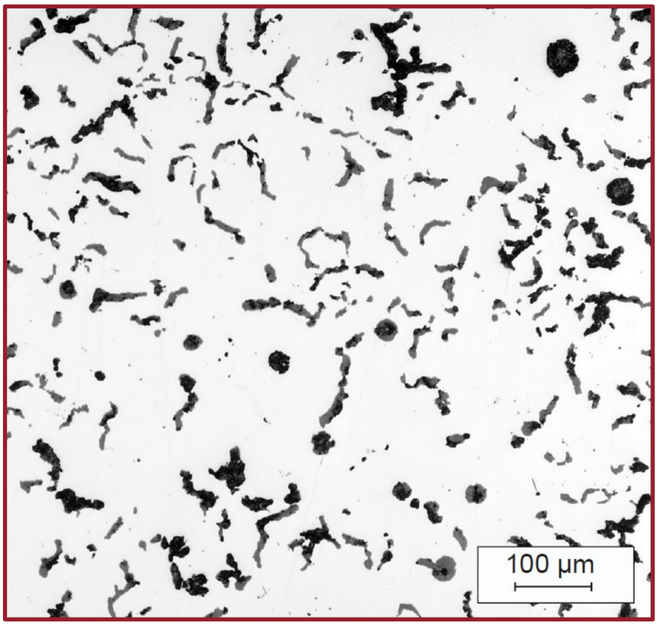

Figure 1: CGI microstructure containing 10% nodularity

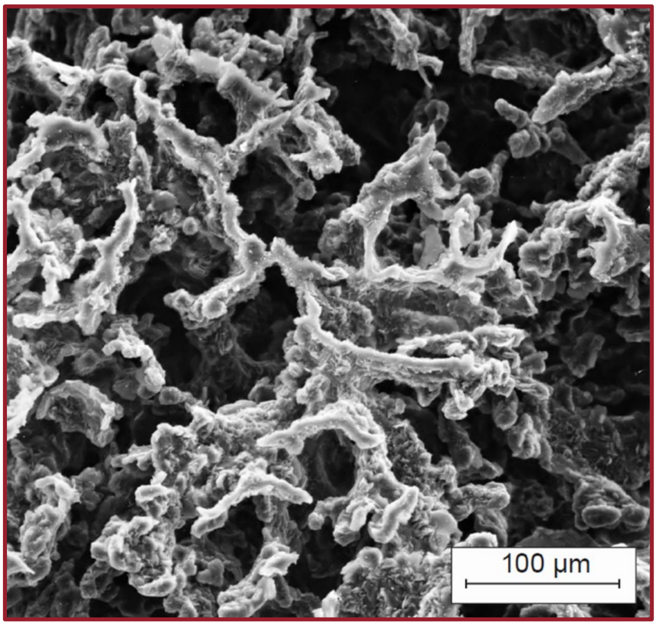

Figure 2: Deep-etched SEM micrographs show the complex coral-like graphite in three-dimensions

Mechanical and Physical Properties of 10% Nodularity CGI – ISO 16112

Property	Test Method	Temp (C°)	GJV 400	GJV 450
Pearlite Content (%)			~ 70	> 90
Ultimate Tensile Strength (MPa)	ASTME 8M (25°C)	25	400–475	450–525
	ASTME 21 (100°C & 300°C)	100	375–450	425–500
		400	300–375	350–425
0.2% Yield Strength (MPa)	ASTME 8M (25°C)	25	280–330	315–365
	ASTME 21 (100°C & 300°C)	100	255–305	290–340
		400	230–280	265–315
Elastic Modulus (GPa)	ASTME 8M (25°C)	25	140–150	145–155
	ASTME 21 (100°C & 300°C)	100	135–145	140–150
		400	130–140	135–145
Elongation (%)	ASTME 8M (25°C)	25	1.0–3.5	1.0–2.5
	ASTME 21 (100°C & 300°C)	100	1.0–3.0	1.0–2.0
		400	1.0–2.5	0.5–1.5
Endurance Ratio	Rotating-Bending	25	0.45–0.50	0.45–0.50
(Fatigue Limit/UTS)	Tension-Compression	25	0.25–0.35	0.25–0.35
	3-point bending	25	0.60–0.70	0.60–0.70
Thermal Conductivity (W/m-K)	Comparative axial heat flow	25	39	38
	ASTME 1225	100	39	37
		400	38	36
Thermal Expansion Coefficient (µm/m-K)	Pushrod dilatometry	100	11.0	11.0
	DIN 51 045	400	12.5	12.5
Poisson's Ratio	ASTME 132	25	0.26	0.26
		100	0.26	0.26
		400	0.27	0.27
0.2% Compressive Yield (MPa)	ASTME 9 (medium length)	25	380–420	410–440
		400	280–320	350–390
Fatigue Strength Reduction Factor	Dependent on notch geometry	25	1.20–1.60	1.20–1.60
Density (g/cc)	Dispacement (750 x 25 x 25) mm	25	7.0–7.1	7.0–7.2
Brinell Hardness (BHN)	10 mm diameter, 3000 kg load	25	183–235	207–255

The Effect of Cooling Rate

The cooling rate of a casting influences the microstructure in three ways. First, higher cooling rates increase the number of eutectic cells per square millimetre, resulting in more grain boundaries that reinforce and strengthen the material. Second, thinner walls (<4~5 mm) with faster cooling will tend to have higher nodularity, perhaps up to 50% Nodularity, providing higher strength, although this effect is less in large components that have high thermal mass. Third, faster cooling rates promote finer pearlite, again increasing strength. For these reasons, smaller components typically have higher mechanical properties than larger components, even if the chemistry and bulk microstructure are the same

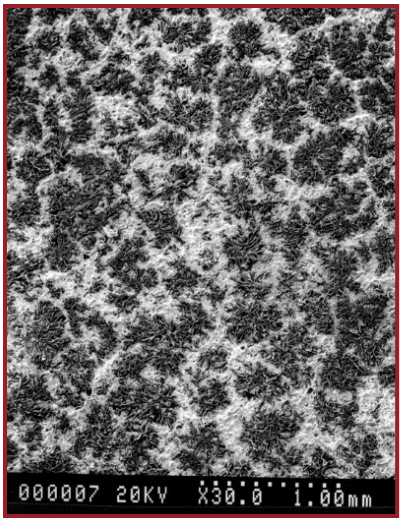

Figure 3: Faster cooling rates result in smaller eutectic cells with more grain boundaries

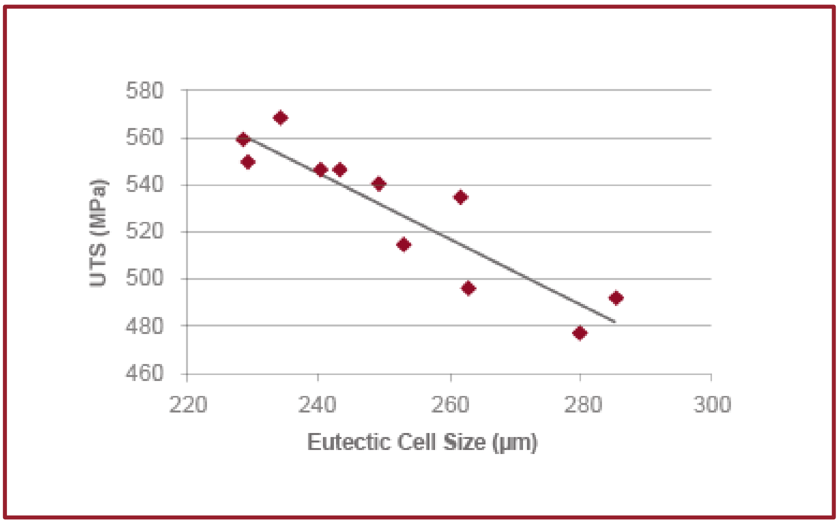

Figure 4: Tensile strength increases as the eutectic cell size decreases