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 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 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

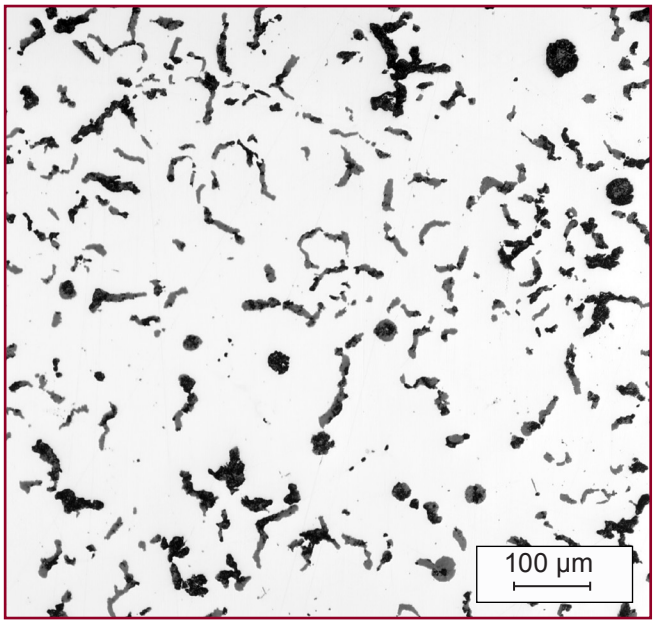

Figure 1: CGI microstructure containing 10% nodularity

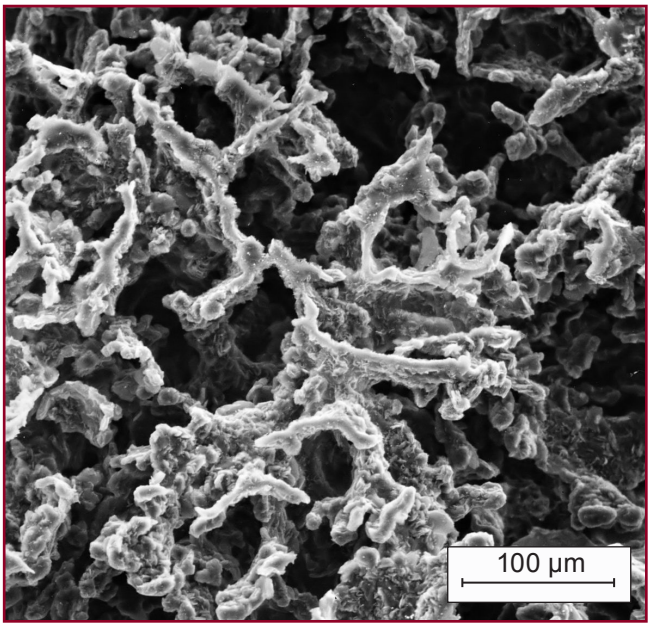

Figure 2: Deep-etched SEM micrographs show the complex coral-like graphite in three-dimensions

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) ASTME 21 (100°C & 300°C)	25 100 400	400-475 375-450 300-375	450-525 425-500 350-425
0.2% Yield Strength (MPa)	ASTME 8M (25°C) ASTME 21 (100°C & 300°C)	25 100 400	280-330 255-305 230-280	315-365 290-340 265-315
Elastic Modulus (GPa)	ASTME 8M (25°C) ASTME 21 (100°C & 300°C)	25 100 400	140-150 135-145 130-140	145-155 140-150 135-145
Elongation (%)	ASTME 8M (25°C) ASTME 21 (100°C & 300°C)	25 100 400	1.0-3.5 1.0-3.0 1.0-2.5	1.0-2.5 1.0-2.0 0.5-1.5
Endurance Ratio (Fatigue Limit/UTS)	Rotating-Bending Tension-Compression 3-point bending	25 25 25	0.45-0.50 0.25-0.35 0.60-0.70	0.45-0.50 0.25-0.35 0.60-0.70
Thermal Conductivity (W/m-K)	Comparative axial heat flow ASTME 1225	25 100 400	39 39 38	38 37 36
Thermal Expansion Coefficient (µm/m-K)	Pushrod dilatometry DIN 51 045	100 400	11.0 12.5	11.0 12.5
Poisson's Ratio	ASTME 132	25 100 400	0.26 0.26 0.27	0.26 0.26 0.27
0.2% Compressive Yield (MPa)	ASTME 9 (medium length)	25 400	380-420 280-320	410-440 350-390
Fatigue Strength Reduction Factor	Dependent on notch geometry	25	1.20-1.60	1.20-1.60
Density (g/cc)	Dispacement (750x25x25) mm	25	7.0-7.1	7.0-7.2
Brinell Hardness (BHN)	10 mm diameter, 3000 kg load	25	183-235	207-255

Thin Wall Data

Higher cooling rates favour the formation of nodular graphite particles and finer pearlite, increasing the mechanical properties. CGI containing 10% nodularity in thick sections (>6mm) may simultaneously contain up to 60% nodularity in thin walls (<4mm), depending on the component design, weight and gating. In components such as cylinder blocks, the higher nodularity in thin-wall areas such as ribs or water jacket and crankcase housings, results in increased strength and stiffness and is beneficial to the product. As these thinner areas are not thermally loaded or heavily machined, design engineers can take advantage of the superior mechanical properties to improve performance, durability and NVH.

Typical properties of ISO Grade GJV 450 as a Function of Nodularity

Property (25°C)	% Nodularity				
	10	30	50	70	90
Tensile Strength (MPa)	465	520	590	640	700
0.2% Yield Strength (MPa)	350	370	390	420	470
Rotating - Bending Fatigue Limit (MPa)	210	220	230	240	255
Elastic Modulus (GPa)	145	150	155	155	160
Elongation (%)	1-2	1-3	2-4	2-5	3-6
Thermal Expansion (at 100 C, µm/m-K)	11.0	11.0	11.0	11.5	12.0
Thermal Conductivity (W/m-K)	36	33	31	28	25