Technical Datasheet CARPENTER TECHNOLOGY

CarTech® BioDur® CCM® Alloy

Type Analysis

Single figures are nominal except where noted.

Carbon (Maximum)	0.10 %	**Manganese (Maximum)**	1.00 %
Silicon (Maximum)	1.00 %	**Chromium**	26.00 to 30.00 %
Nickel (Maximum)	1.00 %	**Molybdenum**	5.00 to 7.00 %
Cobalt	Balance	**Nitrogen (Maximum)**	0.25 %
Iron (Maximum)	0.75 %		

General Information

Description

CarTech BioDur CCM alloy is a non-magnetic cobalt-chromium-molybdenum alloy exhibiting high strength, corrosion resistance, and wear resistance. The alloy is a high nitrogen, low carbon wrought version of ASTM F75 Cast Alloy.

CarTech BioDur CCM alloy also meets the requirements of ASTM F799, ASTM F1537, ISO 5832-4 and ISO 5832-12.

CarTech BioDur CCM alloy is produced by vacuum induction melting (VIM) followed by electroslag remelting (ESR). The finished mill product is supplied in the annealed, hot worked, or warm worked condition.

Applications

CarTech BioDur CCM alloy has been used for machining and forging stock in the orthopedic implant industry for joint replacement and fracture fixation devices such as total hip, knee, and shoulder replacements.

Corrosion Resistance

Important Note: *The following 4-level rating scale is intended for comparative purposes only. Corrosion testing is recommended; factors which affect corrosion resistance include temperature, concentration, pH, impurities, aeration, velocity, crevices, deposits, metallurgical condition, stress, surface finish and dissimilar metal contact.*

Nitric Acid	Excellent	Sulfuric Acid	Good
Phosphoric Acid	Good	Acetic Acid	Excellent
Sodium Hydroxide	Moderate	Salt Spray (NaCl)	Excellent
Sea Water	Good	Humidity	Excellent

Properties

Physical Properties

Specific Gravity	8.29	
Density	0.2990	lb/in³
Mean Specific Heat		
212°F	0.1130	Btu/lb/°F
572°F	0.1260	Btu/lb/°F
1112°F	0.1420	Btu/lb/°F
1652°F	0.1580	Btu/lb/°F
1832°F	0.1590	Btu/lb/°F
2012°F	0.1600	Btu/lb/°F

Specific heat

Temperature		Specific Heat	
°F	°C	Btu/(lb•°F)	(W•S)/(Kg•°K)
212	100	0.113	470
572	300	0.126	524
1112	600	0.142	590
1652	900	0.158	657
1832	1000	0.159	661
2012	1100	0.160	669

Mean CTE		
68 to 212°F	7.32	x 10^{-6} in/in/°F
68 to 392°F	7.36	x 10^{-6} in/in/°F
68 to 572°F	7.48	x 10^{-6} in/in/°F
68 to 752°F	7.66	x 10^{-6} in/in/°F
68 to 932°F	7.86	x 10^{-6} in/in/°F
68 to 1112°F	8.04	x 10^{-6} in/in/°F
68 to 1292°F	8.38	x 10^{-6} in/in/°F
68 to 1472°F	8.61	x 10^{-6} in/in/°F
68 to 1652°F	8.86	x 10^{-6} in/in/°F
68 to 1832°F	9.13	x 10^{-6} in/in/°F
68 to 2048°F	9.19	x 10^{-6} in/in/°F
68 to 2102°F	9.49	x 10^{-6} in/in/°F

Mean coefficient of thermal expansion

Temperature		Mean Coefficient (Micro Inches/Inch)	
68°F to (°F)	20°C to (°C)	per °F	per °C
212	100	7.32	13.18
392	200	7.36	13.25
572	300	7.48	13.47
752	400	7.66	13.79
932	500	7.86	14.15
1112	600	8.04	14.47
1292	700	8.38	15.09
1472	800	8.61	15.50
1652	900	8.86	15.95
1832	1000	9.13	16.44
2048	1120	9.19	16.54
2102	1150	9.49	17.08

Thermal Conductivity		
73°F	87.82	BTU-in/hr/ft²/°F
212°F	100.8	BTU-in/hr/ft²/°F
572°F	131.4	BTU-in/hr/ft²/°F
1112°F	178.8	BTU-in/hr/ft²/°F
1652°F	211.5	BTU-in/hr/ft²/°F
1832°F	221.6	BTU-in/hr/ft²/°F
2012°F	226.9	BTU-in/hr/ft²/°F
2150°F	246.8	BTU-in/hr/ft²/°F

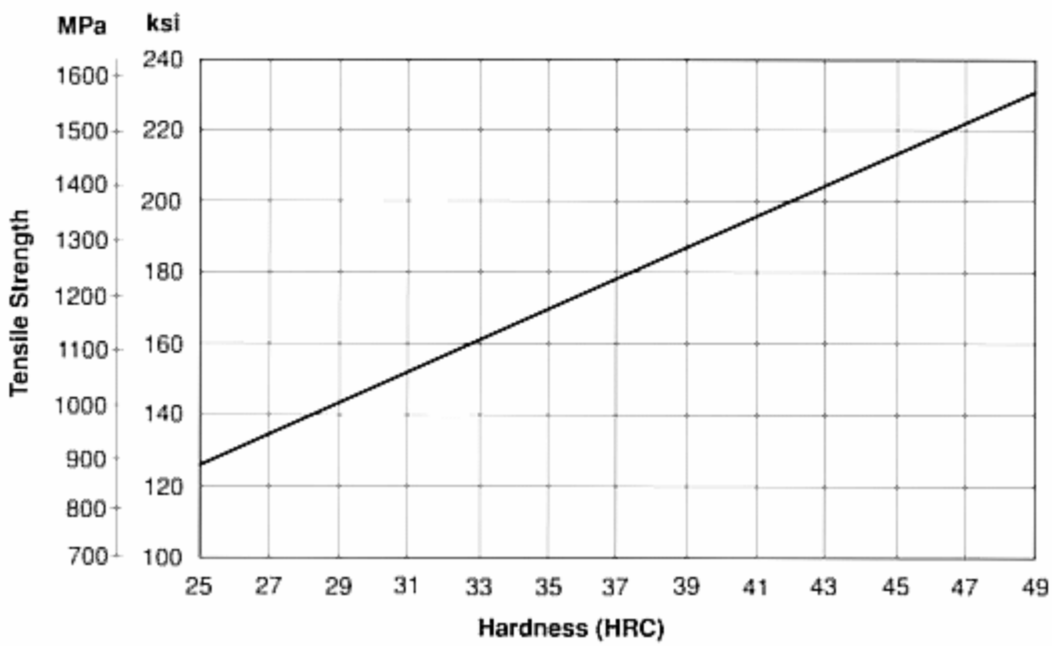
Thermal conductivity

Temperature		Thermal Conductivity	
°F	°C	(Btu•in)/(hr•ft²•°F)	W/(m•K)
73	23	87.82	12.66
212	100	100.80	14.53
572	300	131.36	18.93
1112	600	178.77	25.76
1652	900	211.54	30.49
1832	1000	221.57	31.93
2012	1100	226.94	32.71
2150	1177	246.80	35.57

Poisson's Ratio	0.300
Modulus of Elasticity (E)	35.0 x 10^3 ksi
Modulus of Rigidity (G)	13.4 x 10^3 ksi

Typical Mechanical Properties

Hardness vs. Tensile Strength–BioDur Carpenter CCM Alloy



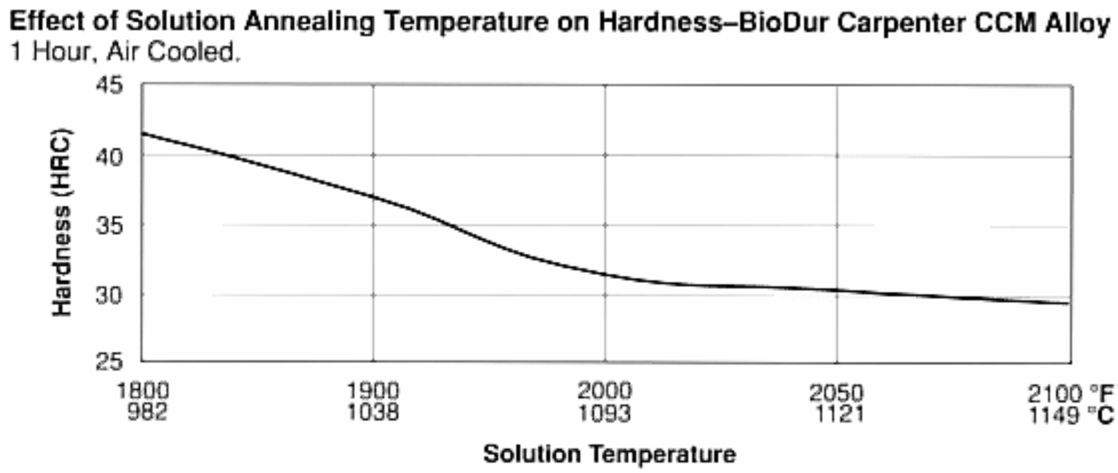
Typical Room Temperature Mechanical Properties–BioDur Carpenter CCM Alloy

Condition	0.2% Yield Strength		Ultimate Tensile Strength		% Elongation in 4D	% Reduction of Area	HRC Hardness
	ksi	MPa	ksi	MPa			
Annealed	85	585	150	1035	25	23	30
Warm Worked	135	930	190	1310	26	23	40
Hot Worked	110	760	160	1100	25	23	33

Heat Treatment

Annealing

BioDur Carpenter CCM alloy is typically annealed at 2000 to 2050°F (1093 to 1121°C) for 1 to 2 hours followed by water quenching. Finer grain size can be maintained through the use of lower annealing temperatures with corresponding increases in annealed hardness.



Workability

Gleeble Testing for Hot Workability

Gleeble* testing is used by Carpenter Technology as a measure of a material's hot workability. On-heating Gleeble data show the general temperature range over which an alloy can be hot worked at a given strain rate, as well as the temperature where the ductility falls to zero (hot shortness).

The temperature corresponding to the peak ductility of the on-heating curve is recommended to be used as the heating temperature for the material. Using this temperature, the Gleeble on-cooling curve is generated. This curve shows relative ductility as a function of temperature and reduction of area. Forty to fifty percent reduction of area is considered acceptable. Fifty to sixty percent is good, sixty to seventy percent is excellent and higher than seventy percent is superior.

On-heating Gleeble test results of both annealed and unannealed BioDur Carpenter CCM alloy are shown in the hyperlink entitled "On-Heating Gleeble Curves." Peak ductility occurs at approximately 2100°F (1149°C). The alloy exhibits superior hot workability at 2200°F (1204°C) and excellent hot workability at 2300°F (1260°C).

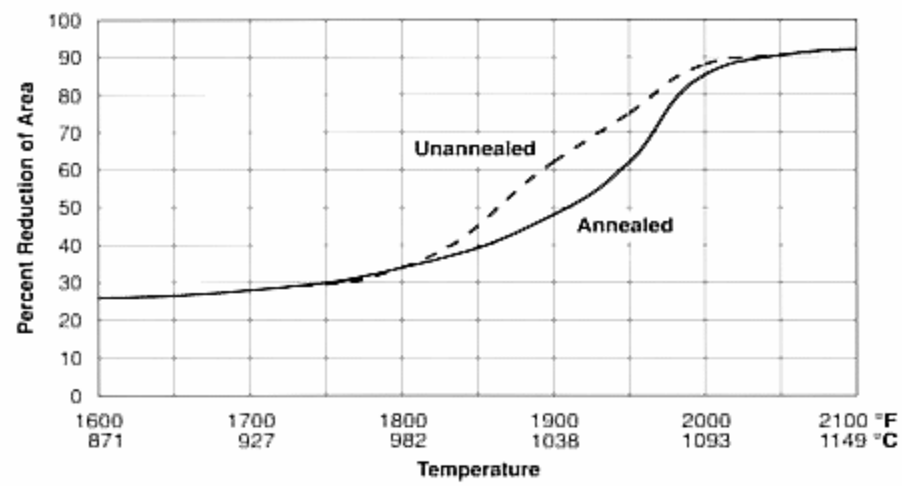
Unannealed BioDur Carpenter CCM alloy possesses better ductility (formability) than annealed material due to finer grain size and is therefore recommended for forging, see hyperlink entitled "On-Cooling Gleeble Curves."

Proper precautions must be taken to ensure accurate furnace temperatures at these higher temperatures to preclude hot shortness. The alloy stiffens rapidly below 2000°F (1093°C) and deformation below 1800°F (982°C) may result in surface tearing.

Proprietary thermomechanical processing techniques are normally required to obtain desired finished mechanical properties and uniformity.

*Gleeble is a registered trademark of Dynamic Systems Inc.

On-Cooling Gleeble Curve from 2100°F (1149°C)–BioDur Carpenter CCM Alloy
Strain Rate-20/sec.



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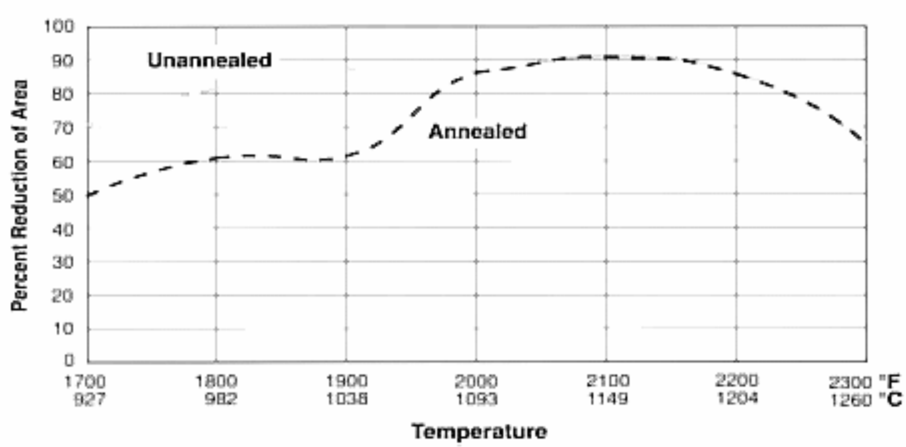
On-Heating Gleeble Curve–BioDur Carpenter CCM Alloy
Strain Rate-20/sec.



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Gleeble Testing for Flow Stress

The hyperlink entitled "Flow Stress Curves" illustrates how the flow stress and strain are related in the range of forging temperatures. The curves in this graph are composed of two different regions: work hardening, where the curves increase to maximum, and dynamic recrystallization, where the curves decrease. BioDur Carpenter CCM alloy exhibits a maximum flow stress at a strain of 0.40.

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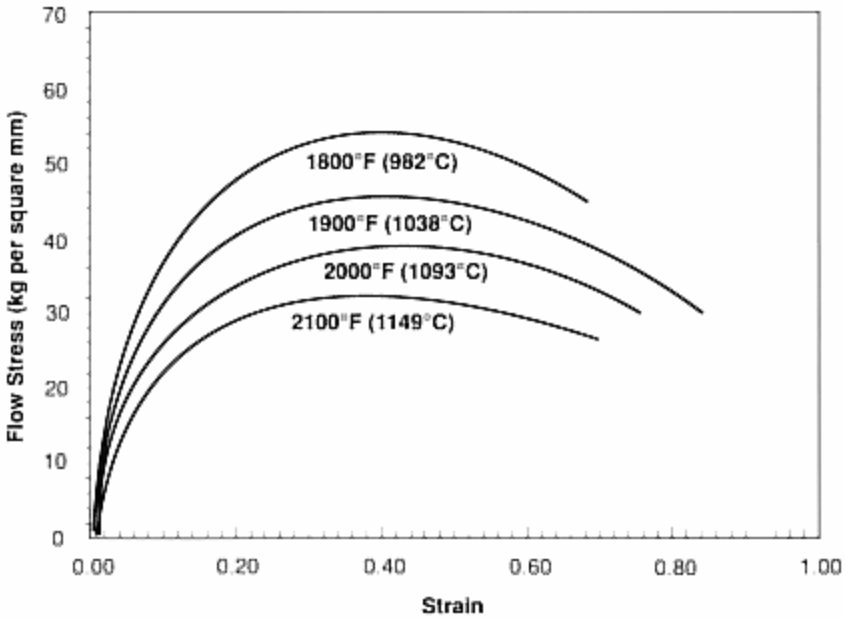
Flow Stress Curves–BioDur Carpenter CCM Alloy
Strain Rate-20/sec.



1 kg per square mm = 1.422 ksi

Cold Working

High strength levels can be achieved in BioDur Carpenter CCM alloy through either hot/cold work or cold work only processes. Significant loss of ductility results from even small amounts of cold work.

Machinability

BioDur Carpenter CCM alloy is difficult to machine in any heat treated condition due to its extremely high work hardening rate, low thermal conductivity, and the presence of hard, abrasive carbides and intermetallics in the microstructure. Tool geometry, rigidity, and adequate machine power are all extremely important considerations.

The hyperlink titled "Machinability Tables" shows typical feeds and speeds for BioDur Carpenter CCM alloy.

Turning—Single point and box tools

Condition	Depth of Cut In.	High Speed Tool Speed fpm	High Speed Tool Feed ipr	High Speed Tool Tool Mtl.	Carbide Tool Speed fpm Brazed	Carbide Tool Speed fpm Throw away	Carbide Tool Feed ipr	Carbide Tool Tool Mtl.
BHN less than 260	.100	20	.010	M-42	70	80	.010	C-2
	.025	25	.007		90	100	.007	C-3
BHN 260 to 340	.100	15	.010	M-47	65	75	.010	C-2
	.025	25	.007		80	95	.007	C-3
BHN greater than 340	.100	12	.010	M-42	60	70	.010	C-2
	.025	15	.005	M-47	70	80	.007	C-3

Turning—Cutoff and form tools

Condition	Speed fpm	Feed ipr Cutoff Tool Width, Inches 1/16	1/8	1/4	Feed ipr Form Tool Width, Inches 1/2	1	1 1/2	2	Tool Mtl.
BHN less than 300	15	.002	.004	.005	.004	.002	.002	.001	M-42
	45	.003	.0045	.006	.004	.003	.0025	.0015	C-2
BHN greater than 300	15	.002	.003	.004	.003	.002	.002	.001	M-42
	45	.003	.003	.0045	.003	.0025	.002	.001	C-2

Drilling

Condition	Speed fpm	Feed ipr Nominal Hole Diameter, Inches 1/16	1/8	1/4	1/2	3/4	1	1 1/2	2	Tool Mtl.
BHN less than 300	20	—	.002	.003	.003	.004	—	—	—	M-42
BHN greater than 300	15	—	.002	.003	.003	.004	—	—	—	

Tapping

Condition	Speed fpm	Tool Mtl.
BHN less than 300	10	M-1; M-7; M-10
BHN greater than 300	7	M-1; M-7; M-10; Nitrided

Threading, Die

Condition	Speed fpm				Tool Mtl.
	7 or less	8 to 15	16 to 24	25 and up T.P.I.	
BHN less than 300	4-6	5-8	6-10	8-12	M-2; M-7; M-10
BHN greater than 300	3-4	3-5	4-8	5-10	M-42

Milling, End—Peripheral

Condition	Depth of Cut In.	High Speed Tool						Carbide Tool					
		Speed fpm	Feed—Inches per tooth Cutter Diam. Inches				Tool Mtl.	Speed fpm	Feed—Inches per tooth Cutter Diam. Inches				Tool Mtl.
			1/4	1/2	3/4	1-2			1/4	1/2	3/4	1-2	
BHN less than 300	.050	15	.002	.002	.003	.004	M-42	60	.001	.002	.003	.004	C-2
BHN greater than 300		12	.0015	.0015	.002	.003		50	.0015	.0015	.002	.003	

Broaching

Condition	Speed fpm	Chip Load Inches per Tooth	Tool Mtl.
BHN less than 300	8	.002	M-42
BHN greater than 300	6	.002	

Reaming

Condition	High Speed Tool								Carbide Tool	
	Speed fpm	Feed Inches Per Rev Reamer Diam. Inches						Tool Mtl.	Speed fpm	Tool Mtl.
		1/8	1/4	1/2	1	1 1/2	2			
BHN less than 300	20	.002	.006	.008	.010	.012	.014	M-42	60	C-2
BHN greater than 300	15	.002	.006	.008	.010	.012	.014	M-42	50	C-2

Sawing, power hack saw

Condition	Pitch—Teeth Per Inch Material Thickness, Inches				Speed	Feed
	Under 1/4	1/4 to 3/4	3/4 to 2	Over 2	Strokes/ Minute	Inches/ Stroke
All Conditions	10	6	6	4	30-60	.003-.006

Other Information

Applicable Specifications

- ASTM F1537
- ASTM F799
- ISO 5832-4
- ASTM F75
- ISO 5832-12

Forms Manufactured

- Bar-Rounds
- Wire
- Billet
- Wire-Rod

Technical Articles

- A Guide to Etching Specialty Alloys for Microstructural Evaluation
- Benefits of P/M Processed Cobalt-Based Alloy for Orthopaedic Medical Implants
- Effect of Cold Drawing and Heat Treating on Powder Metallurgy Processed ASTM F 1537 Alloy 1 & Alloy 2 Barstock
- Higher Performance Material Solutions for a Dynamic Spine Market
- Unique Properties Required of Alloys for the Medical and Dental Products Industry

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