CARPENTER® TECHNOLOGY

DATASHEET

BIODUR® 316LS STAINLESS

Applicable specifications: ASTM F138, ASTM F139, ISO 5832-1 Composition D

Associated specifications: UNS S31673

Type analysis

Single figures are nominal except where noted.

Iron	Balance	**Chromium**	17.00–19.00 %	**Nickel**	13.00–15.00 %
Molybdenum	2.25–3.00 %	**Manganese**	Max 2.00 %	**Silicon**	Max 0.75 %
Copper	Max 0.50 %	**Nitrogen**	Max 0.10 %	**Cobalt**	< 0.10 %
Carbon	Max 0.030 %	**Phosphorus**	Max 0.025 %	**Sulfur**	Max 0.010 %

Forms manufactured

Bar-Flats	**Bar-Hexagons**	**Bar-Rounds**	**Bar-Squares**	**Sheet**	**Strip**	**Wire**

Description

BioDur 316LS stainless is an electro-slag remelted (ESR) or vacuum arc remelted (VAR), low-carbon, high- nickel and molybdenum version of 316 stainless. The secondary premium melting step (ESR or VAR) imparts improved cleanliness. The chemistry modifications are designed to maximize the corrosion resistance of this alloy and provide a ferrite-free microstructure. The alloy is non-magnetic, even after severe cold forming operations.

The chemistry of BioDur 316LS stainless meets the recently implemented **EU MDR** regulatory labeling threshold of less than 0.10% cobalt by weight. Devices made from this alloy should not need to be labeled as containing a potential CMR (carcinogenic, mutagenic and reprotoxin) element.

Key Properties:

- EU MDR compliance
- Corrosion resistance
- Improved cleanliness
- Non-magnetic, ferrite-free

Markets:

- Medical

Applications:

- Fracture fixation devices
- Surgical implant devices
- Surgical instruments

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Corrosion resistance

BioDur 316LS stainless is balanced, with higher chromium, nickel, and molybdenum than standard Type 316L stainless, thus increasing its resistance to pitting corrosion. This increased resistance to pitting is illustrated by a Pitting Resistance Equivalent (PRE) of greater than 26, as opposed to a PRE of 23 for standard Type 316L stainless.* This chemistry balance, combined with the exceptional cleanliness from the VAR remelt practice and absence of ferrite, makes BioDur 316LS stainless an excellent candidate for orthopedic applications.

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

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

Physical properties

PROPERTY	At or From	English Units
SPECIFIC GRAVITY	—	7.95
DENSITY	—	0.2870 lb/in^3
MEAN SPECIFIC HEAT	32 to 212°F	0.1200 Btu/lb/°F
MEAN CTE	32 to 1200°F	10.3 x 10^{-6} in/in/°F
ELECTRICAL RESISTIVITY	70°F	445.0 ohm-cir-mil/ft

**Pitting Resistance Equivalent = 26.00 min. Pitting Resistance Equivalent (PRE) = 3.3 x Mo + Cr.*

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Typical mechanical properties

BioDur 316LS stainless is supplied in the unannealed, annealed, or cold worked condition. Mechanical properties can be tailored to specific applications by changing the cold work percentage. In general, the acceptable property ranges are dependent on bar size due to varying penetration of cold work.

The following tables list the maximum specified tensile minimums for various size ranges and the typical mechanical properties for commonly produced tensile requirements.

MAXIMUM SPECIFIED TENSILE MINIMUMS

DIAMETER		ULTIMATE TENSILE STRENGTH	
IN	mm	ksi	MPa
Up to 0.250	Up to 6.3	175	1207
0.251–0.500	6.31–12.7	165	1138
0.501–1.000	12.71–25.4	155	1069
1.001–1.500	25.41–38.1	125	862
1.501–1.750	38.11–44.5	95	655
Over 1.750	Over 44.5	85	586

BAR AND WIRE

CONDITION	COLD WORK	0.2% YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONGATION IN 4D	REDUCTION OF AREA	HARDNESS
	%	ksi	MPa	ksi	MPa	%	%	HRC
Annealed	—	36	248	85	586	57	88	88 HRB
Cold Worked	35	115	793	125	862	18	72	26
	48	120	827	145	1000	16	69	32
	52	123	848	150	1034	16	65	34
	60	128	883	160	1103	16	62	36
	70	130	896	170	1172	15	60	38
	80	137	945	180	1241	13	57	40

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STRIP UP TO 0.120 IN. THICK						
CONDITION	**COLD WORK**	**0.2% YIELD STRENGTH**		**ULTIMATE TENSILE STRENGTH**		**ELONGATION IN 4D**
	%	**ksi**	**MPa**	**ksi**	**MPa**	**%**
Annealed	—	44	303	89	613	44
Cold Worked	15	82	565	112	772	27
	25	106	730	126	868	17
	35	130	896	140	965	7
	45	145	999	154	1061	5

Meets ASTM F139 and ISO 5832-1 Composition D specifications.

Heat treatment

Annealing	Annealing is accomplished by heating in the range of 1800/2050°F (982/1121°C). Typically, the alloy is annealed at the lower end of this range to preserve the fine grain size that is required for medical applications.
Hardening	BioDur 316 LS stainless cannot be hardened by heat treatment. It must be hardened by cold working.

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Workability

Hot Working	BioDur 316LS stainless can be readily forged, upset, and hot headed. To forge, heat uniformly to 2100/2300°F (1149/1260°C). Forgings may be air cooled. Best corrosion resistance is obtained if the forgings are given a subsequent anneal followed by a rapid quench.
Cold Working	BioDur 316LS stainless can be deep drawn, stamped, headed, and upset without difficulty.
Machinability	The intentional reduction of sulfur in BioDur 316LS stainless, the cleanliness due to the VAR premium melting practice, and the typically highly cold worked structure make machining more difficult than standard Type 316L stainless. Rigidly supported tools, as heavy a cut as possible, and positive feed should be used to prevent glazing. For more detailed machining recommendations for Type 316L stainless, consult the "Guide to Machining Carpenter Specialty Alloys".
Additional Machinability Notes	When using carbide tools, surface speed feet/minute (SFPM) can be increased between 2 and 3 times over the high-speed suggestions. Feeds can be increased between 50 and 100%. Figures used for all metal removal operations covered are average. On certain work, the nature of the part may require adjustment of speeds and feeds. Each job has to be developed for best production results with optimum tool life. Speeds or feeds should be increased or decreased in small steps.
Weldability	BioDur 316LS stainless can be satisfactorily welded by the conventional automatic and manual electric-arc techniques. The low carbon content reduces the susceptibility to carbide precipitation in the heat affected zone; however, when optimum corrosion resistance is required, a post weld anneal is always considered good practice. Filler metal should be the same alloy as the parent. Because this alloy is balanced to have zero ferrite potential, it is more susceptible to weld hot cracking than standard Type 316L stainless. This effect may be minimized by keeping heat inputs, base metal dilution, and joint restraint to a minimum.

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Typical feeds and speeds

The feeds and speeds in the following charts are conservative recommendations for initial setup. Higher feeds and speeds may be attainable depending on machining environment. See the additional machinability notes above.

TURNING — CUT-OFF AND FORM TOOLS

SPEED, FPM	FEED, IPR							TOOL MATERIAL
	CUT-OFF TOOL WIDTH, IN				FORM TOOL WIDTH, IN			
	1/16	*1/8*	*1/4*	*1/2*	*1*	*1-1/2*	*2*	
56–85	.001	.0015	.002	.0015	.001	.001	–	M-2

ROUGH REAMING

HIGH-SPEED TOOLS		CARBIDE TOOLS		FEED, IPR, REAMER DIAMETER, IN					
SPEED, FPM	TOOL MATERIAL	SPEED, FPM	TOOL MATERIAL	*1/8*	*1/4*	*1/2*	*1*	*1-1/2*	*2*
70	M-7	–	–	.003–.008	.003–.008	.003–.008	.012–.018	.012–.018	.012–.018

DRILLING — HIGH-SPEED TOOLS

SPEED, FPM	FEED, IPR								TOOL MATERIAL
	NOMINAL HOLE DIAMETER, IN								
	1/16	*1/8*	*1/4*	*1/2*	*3/4*	*1*	*1-1/2*	*2*	
50–60	–	–	.004	–	.010	–	–	–	M-1, M-10

DIE THREADING — HIGH-SPEED TOOLS

SPEED, FPM				TOOL MATERIAL
7 OR LESS, TPI	8 TO 15, TPI	16 TO 24, TPI	25 AND UP, TPI	
8–15	10–20	15–25	15–25	M-1, M-2, M-7, M-10

MILLING — END PERIPHERAL

DEPTH OF CUT, IN	HIGH-SPEED TOOLS					
	SPEED, FPM	FEED, IN PER TOOTH				TOOL MATERIAL
		CUTTER DIAMETER, IN				
		1/4	*1/2*	*3/4*	*1-2*	
.050	75	.001–.004	.001–.004	.001–.004	.001–.004	M-2, M-7

TAPPING — HIGH-SPEED TOOLS

SPEED, FPM	TOOL MATERIAL
20	M-1, M-7, M-10

BROACHING — HIGH-SPEED TOOLS

SPEED, FPM	CHIP LOAD, IPT	TOOL MATERIAL
15	.003	M-2, M-7

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