PYROWEAR® 53

Applicable designation: AMS 6308

Associated specification: UNS K71040

Type analysis

Single figures are nominal except where noted.

Iron	Balance	**Molybdenum**	3.25 %	**Copper**	2.00 %
Nickel	2.00 %	**Chromium**	1.00 %	**Silicon**	1.00 %
Manganese	0.35 %	**Carbon**	0.10 %	**Vanadium**	0.10 %

Forms manufactured

Bar	**Bar-Rounds**	**Billet**

Description

Pyrowear 53 is a premium quality carburizing gear steel with a combination of high-temperature performance, fatigue resistance, deep hardenability, and excellent toughness. The alloy has a resisted softening at elevated service temperatures and possesses good temper resistance and high case hot hardness while maintaining high core impact strength and fracture toughness. Pyrowear 53 is triple vacuum processed by vacuum induction melting, followed by two cycles of vacuum arc remelting (VIM-VAR-VAR) to provide superior cleanliness and optimum metallurgical quality.

Key Properties:

- High-temperature performance
- High core impact strength
- Excellent toughness
- Fatigue resistance
- High case hot hardness

Markets:

- Aerospace
- Defense

Applications:

- Gears

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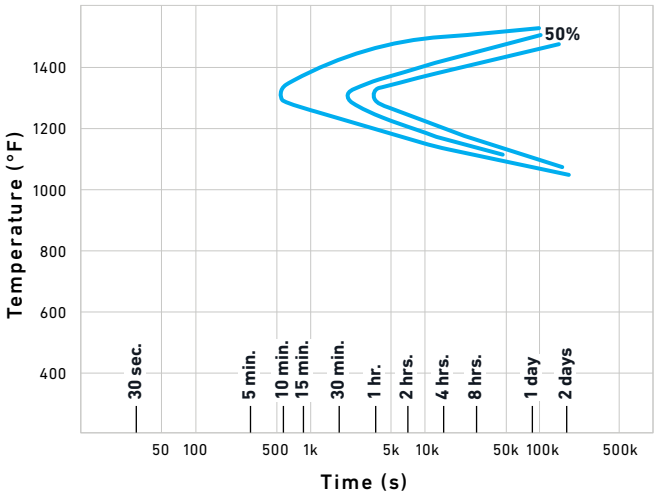
Physical properties

PROPERTY		At or From	English Units	Metric Units
MEAN COEFFICIENT OF THERMAL EXPANSION (CTE)		75 to 200°F (24 to 93°C)	6.26 x 10^{-6} in/in/°F	11.26 x 10^{-6} length/length/°C
		75 to 300°F (24 to 149°C)	6.46 x 10^{-6} in/in/°F	11.62 x 10^{-6} length/length/°C
		75 to 400°F (24 to 204°C)	6.59 x 10^{-6} in/in/°F	11.82 x 10^{-6} length/length/°C
		75 to 500°F (24 to 260°C)	6.70 x 10^{-6} in/in/°F	12.06x 10^{-6} length/length/°C
		75 to 600°F (24 to 316°C)	6.81 x 10^{-6} in/in/°F	12.25 x 10^{-6} length/length/°C
		75 to 700°F (24 to 371°C)	6.90 x 10^{-6} in/in/°F	12.42 x 10^{-6} length/length/°C
		75 to 800°F (24 to 427°C)	7.06 x 10^{-6} in/in/°F	12.70 x 10^{-6} length/length/°C
		75 to 900°F (24 to 482°C)	7.16 x 10^{-6} in/in/°F	12.88 x 10^{-6} length/length/°C
		75 to 1000°F (24 to 538°C)	7.25 x 10^{-6} in/in/°F	13.05 x 10^{-6} length/length/°C
		75 to 1100°F (24 to 593°C)	7.33 x 10^{-6} in/in/°F	13.19 x 10^{-6} length/length/°C
		75 to 1200°F (24 to 649°C)	7.41 x 10^{-6} in/in/°F	13.33 x 10^{-6} length/length/°C
		75 to 1300°F (24 to 704°C)	7.48 x 10^{-6} in/in/°F	13.46 x 10^{-6} length/length/°C
		75 to 1400°F (24 to 760°C)	7.51 x 10^{-6} in/in/°F	13.51 x 10^{-6} length/length/°C
CRITICAL TEMPERATURE (AC1)	CORE	1505°F (819°C)		
	CASE	1340°F (727°C)		
CRITICAL TEMPERATURE (AC3)	CORE	1605°F (874°C)		
	CASE	1455°F (791°C)		
MARTENSITE START	CORE	950°F (510°C)		
	CASE	265°F (130°C)		
MARTENSITE FINISH	CORE	675°F (357°C)		
	CASE	-155°F (-104°C)		

TTT CURVES, AUSTENITIZING TEMPERATURE—1675°F (913°C)



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Typical mechanical properties

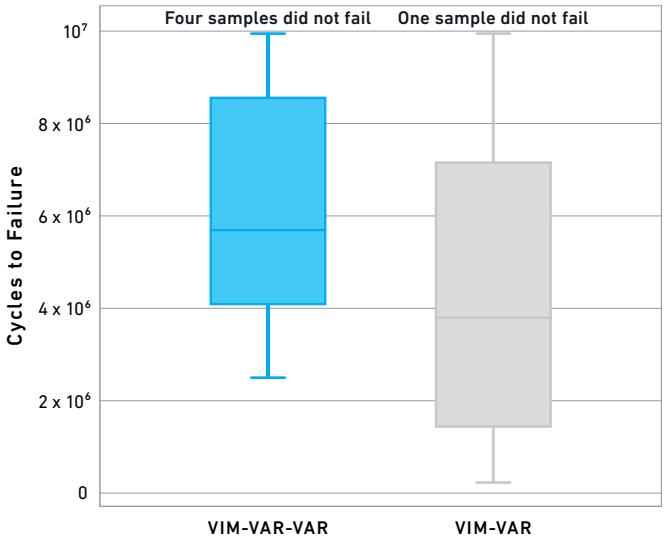
CORE MECHANICAL PROPERTIES

Test material prepared as follows: Pseudocarburized (in inert atmosphere) 1700°F (927°C), 7 hours. Hardened 1675°F (913°C) 25 minutes, oil quench. Refrigerated -100°F (-73°C), 0.5 hour. Tempered 400°F (204°C), 2 hours + 2 hours.

TEST TEMPERATURE		YIELD STRENGTH		ULTIMATE TENSILE STRENGTH		ELONGATION IN 4D	REDUCTION OF AREA	CHARPY V-NOTCH IMPACT	
°F	°C	ksi	MPa	ksi	MPa	%	%	ft-lbs	J
-65	-54	160	1103	193	1331	18	63	39–41	53–56
RT	RT	140	965	170	1172	16	66.5	87–95	118–129
212	100	—	—	—	—	—	—	103–120	140–163
350	177	130	896	175	1207	12	46	114–116	155–157

AXIAL FATIGUE PERFORMANCE

The VIM-VAR-VAR melt process provides improved fatigue life by refining microstructural cleanliness. Test conditions: R = -1, +/- 89 ksi, 20 Hz.



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EFFECT OF AUSTENITIZING TEMPERATURE

Test material prepared as follows: Pseudocarburized (in inert atmosphere) 1700°F (927°C), 7 hours. Hardened from temperatures indicated below by oil quenching or air cooling. Refrigerated -100°F (-73°C), 0.5 hour. Tempered 500°F (260°C), 2 hours + 2 hours.

CHARPY V-NOTCH IMPACT STRENGTH — ROOM TEMPERATURE

AUSTENITIZING TEMPERATURE (25 MIN AT TEMP)		OIL QUENCHED			AIR COOLED		
		CVN IMPACT		HARDNESS HRC	CVN IMPACT		HARDNESS HRC
°F	°C	ft-lbs	J		ft-lbs	J	
1650	899	106, 97, 93	144, 132, 126	34	91, 91, 84	123, 123, 114	34.5
1700	927	96, 98, 84	130, 133, 114	37.5	73, 75, 67	99, 102, 91	36.5
1750	954	54, 54, 64	73, 73, 87	36.5	40, 52, 44	54, 71, 60	36
1800	982	71, 67, 62	96, 91, 84	38.5	56, 44, 51	76, 60, 69	38
1850	1010	68	—	39	54, 61, 65	73, 83, 88	39

FRACTURE TOUGHNESS

Fracture toughness tests were conducted on samples taken from an 8.75 in. round bar. Samples were austenitized in neutral salt at 1675°F (913°C) for 35 minutes, oil quenched, deep frozen at -100°F (-73°C) for 1 hour, and tempered at 500°F (260°C) for 4 hours. Testing was done per ASTM E399 at room temperature.

SAMPLE ORIENTATION	HARDNESS (HRC)	K_{IC}	ksi$\sqrt{in}$
L-R	36	115	120
R-L	36	115	120
C-R	36	115	120

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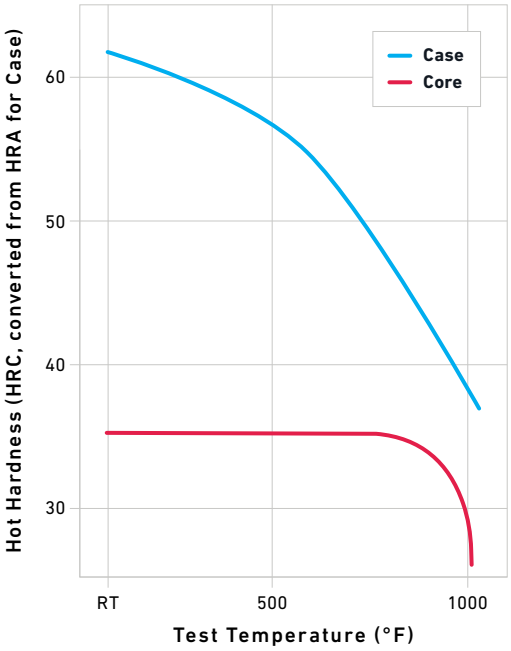
HOT HARDNESS

Hot hardness tests were conducted on the case and core of Pyrowear 53. The test samples were prepared as follows: Carburized (7°F [-14°C] dew point) or pseudocarburized (in inert atmosphere) 1700°F (927°C), 7 hours. Hardened 1675°F (913°C), 25 minutes, oil quench. Refrigerated -100°F (-73°C), 0.5 hour. Tempered 400°F (204°C), 2 hours + 2 hours.



Heat treatment

Decarburization	Pyrowear 53 must be carburized to produce a carbon-rich case prior to hardening. As with all carburizing alloys, precautions must be taken to avoid decarburization during the hardening operation. A controlled-atmosphere furnace or neutral salt bath is suggested for hardening carburized parts.
Normalizing	Forgings are normalized by heating rapidly to 1850°F (1010°C) and cooling in air.
Annealing	Heat to 1285/1315°F (696/713°C), hold 4 to 8 hours and cool slowly in the furnace. Maximum hardness is 248 Brinell. To relieve machining stresses, heat to 1100°F (593°C), hold for 1 hour at heat, then air cool.

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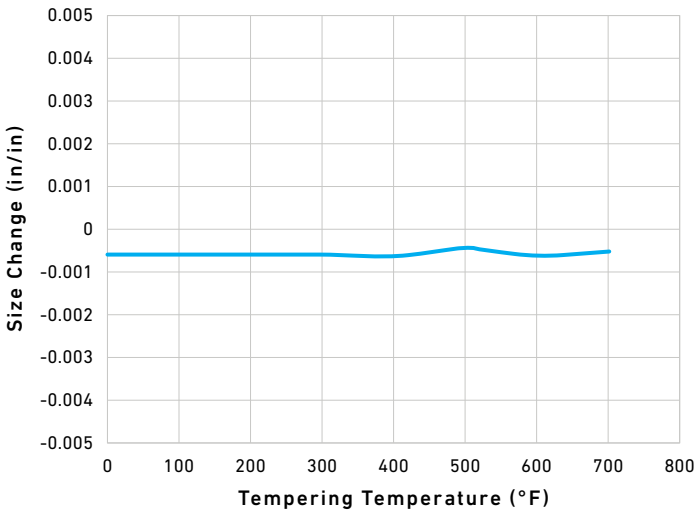
Carburizing	Carburizing may be performed in a pack or in gas. A more uniform gas carburization may be obtained by heating to carburizing temperatures before introducing the carburizing atmosphere. Carburize between 1600/1700°F (871/927°C) for a period long enough to secure the desired case. A Rockwell C 55 case depth of about 0.040 in. and a total case depth of about 0.065 in. with a maximum carbon content in the case of about 0.80% were obtained by gas carburizing at 1700°F (927°C) for 7 hours in a laboratory endothermic atmosphere furnace at a dew point of 7°F (-14°C). The part may be hardened directly from carburizing by furnace cooling to 1675°F (913°C), followed by oil quenching to room temperature. Direct hardening after carburizing does not result in an ideal case structure of optimum impact properties. For improved toughness, cool to room temperature after carburizing, anneal and harden by oil quenching from 1675°F (913°C). Expected core hardness is Rockwell C 34/37.
Hardening	Pyrowear 53 can be hardened by air cooling or oil quenching from 1660/1690°F (904/921°C). Oil quenching produces the optimum core impact strength.
Deformation (size change) in hardening	Although Pyrowear 53 is air hardenable, oil quenching is recommended for optimum impact properties. To minimize size change and warpage during heat treatment, the alloy may be air hardened, but with some loss of impact strength.
Cold treatment	To obtain maximum case hardness and dimensional stability, cold treating after hardening is recommended. This is performed by holding the material for 1 hour at a temperature below -100°F (-73°C) and allowing a natural return to room temperature. The part should be tempered after the sub-zero treatment.
Tempering	Pyrowear 53 is designed to possess significantly greater case temper resistance than conventional alloys such as AISI 9310, 3310, or 8620.

SIZE CHANGE

Samples oil quenched from 1675°F (913°C) and tempered 4 hours at temperatures below.



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CASE AND CORE HARDNESS

Test material prepared as follows: Tempering for 1 hour or for 2 hours + 2 hours after hardening and sub-zero treatments. For applications requiring greater dimensional stability, the 2 hour + 2 hour temper is suggested.

TEMPERING TEMPERATURE		HARDNESS (HRC) CORE		HARDNESS (HRC) CASE	
°F	°C	TEMPERED 1 HR	TEMPERED 2 + 2 HRS	TEMPERED 1 HR	TEMPERED 2 + 2 HRS
As quenched and refrigerated		34	34	66.5	66.5
300	149	35	34.5	63	62.5
350	177	35	35	62	62
400	204	34.5	35	61.5	62
450	232	35	35	61.5	61.5
500	260	35	—	61	—
550	288	35	—	61	—

Workability

Forging	Heat uniformly to a temperature of 2000/2050°F (1093/1121°C). Do not forge below 1700°F (927°C). Forgings may be individually air cooled. Intricate forgings may be buried in vermiculite or furnace cooled.

For additional information, please contact your nearest sales office:
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