SOONV® alloy 625LCF

SOONV® alloy 625LCF (UNS N06626 / W. Nr. 2.4856) was developed as a fatigue-resistant, bellows-quality version of SOONV alloy 625. Alloying, melting and processing are designed and controlled to provide a sheet product with optimum resistance to low-cycle and thermal fatigue at up to 1200°F (650°C). The alloy offers a high level of performance in aircraft exhaust and automotive flexible coupling bellows, expansion joints in process or transport piping, and other applications involving resistance to low-cycle or thermal fatigue.

Table 1 - Limiting Chemical Composition, wt %*

Nickel	58.0 min.
Chromium	20.0-23.0
Molybdenum	8.0-10.0
Niobium[a]	3.15-4.15
Iron	5.0 max.
Carbon	0.03 max.
Manganese	0.50 max.
Silicon	0.15 max.
Sulfur	0.015 max.
Aluminum	0.40 max.
Titanium	0.40 max.
Phosphorus	0.015 max.
Cobalt	1.0 max.
Nitrogen	0.02 max.

*UNS N06626 [a]Plus Ta.

Physical Properties

Table 3 - Physical Properties

Density, lb/in^3	0.305
g/cm^3	8.44
Melting Range, °F	2350-2460
°C	1290-1350
Curie Temperature, °F	<-320
°C	<-196
Permeability at 200 oersted (15.9 kA/m)	1.0006

Thermal and Electrical Properties

Table 2 - Thermal and Electical Properties

Temperature °F	Coefficient of Expansion[a] 10^{-6}in/in•°F	Thermal Conductivity Btu• in/ ft^2-h•°F	Specific Heat Btu/lb•°F	Electrical Resistivity ohm-circ mil/ft	Temperature °C	Coefficient of Expansion[a] µm/m•°C	Thermal Conductivity W/m•°C	Specific Heat J/kg•°C	Electrica Resistivit µΩ-m
-250	-	50	-	-	-150	-	7.4	-	-
-200	-	52	-	-	-100	-	7.9	-	-
-100	-	58	-	-	-50	-	8.7	-	-
0	-	64	0.096	-	20	-	9.7	410	1.29
70	-	68	0.098	776	100	12.8	11.0	429	1.32
200	7.1	75	0.102	794	200	13.1	12.4	454	1.34
400	7.3	87	0.109	806	300	13.3	13.8	479	1.35
600	7.4	98	0.115	812	400	13.7	15.3	502	1.36
800	7.6	109	0.122	818	500	13.9	16.9	528	1.37
1000	7.8	121	0.128	830	600	14.4	18.3	553	1.38
1200	8.2	132	0.135	830	700	14.9	19.8	578	1.38

[a]Mean coefficient of linear expansion between 70°F (21°C) and temperature shown.

Modulus of Elasticity

Table 4 - Modulus of Elasticity

Temperature °F	Young's Modulus ksi x 10^3	Shear Modulus ksi x 10^3	Poisson's Ratio μ	Temperature °C	Young's Modulus GPa	Shear Modulus GPa	Poisson's Ratio μ
70	30.1	11.8	0.28	20	208	81.4	0.28
200	29.6	11.6	0.28	100	203	79.3	0.28
400	28.7	11.1	0.29	200	198	76.9	0.29
600	27.8	10.8	0.29	300	192	74.5	0.29
800	26.9	10.4	0.29	400	187	72.4	0.29
1000	25.9	9.9	0.31	500	181	69.6	0.30
1200	24.7	9.4	0.31	600	174	66.5	0.31
-	-	-	-	700	166	62.7	0.32

Room-Temperature Mechanical Properties

SOONV alloy 625LCF has an average grain size of ASTM No. 5 (0.0025 in/0.064 mm) or finer. The outstanding characteristic of this alloy is its low-cycle fatigue strength derived primarily from controlled microstructure, grain size and yield strength.

The same factors that enhance resistance to mechanical fatigue also improve resistance to thermal fatigue. The alloy, like alloy 625, undergoes a microstructural phase formation during long-time exposure to intermediate elevated temperatures. Such exposure can increase the strength of the alloy while lowering ductility and impact properties. Because of the phase formation, with the unfavorable effect of fine grain on creep-rupture properties, SOONV alloy 625LCF is not recommended for extended use at high stress levels above 1200°F (650°C).

Table 5 - Room-Temperature Mechanical Properties[a]

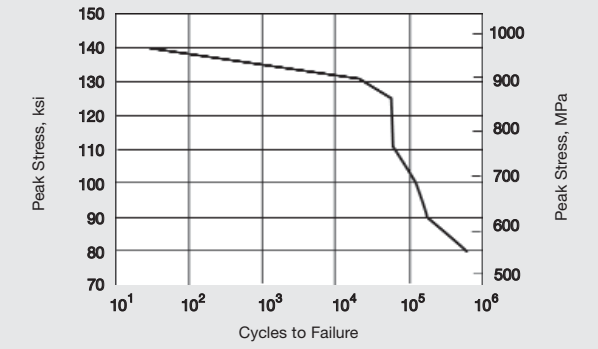
Minimum Tensile Strength, ksi	120
MPa	827
Minimum Yield Strength (0.2% Offset)	
ksi	60
MPa	414
Minimum Elongation, %	40
Bend Tent:	
Thicknesses of 0.050 in (1.27 mm) and under	1T
Thicknesses over 0.050 in (1.27 mm) through 0.100 in (2.54 mm)	2T

*Yield strength requirement may not apply to sheet thickness under 0.010 in (0.25 mm). Elongation requirement may not apply to thicknesses under 0.005 in (0.13 mm). All requirements are at room temperature.

Table 6 - Effect of Long-Time Exposure to 1200°F (650°C) on Room-Temperature Properties

Exposure Time	Yield Strength (0.2% Offset)		Tensile Strength		Elongation	Hardness
Months	ksi	MPa	ksi	MPa	%	%
As Annealed	66.4	458	130.4	899	49	92b
3	132.8	916	177.7	1225	24	35
6	131.3	905	179.5	1238	23	35
9	132.7	915	187.9	1296	17	36
12	132.2	912	180.9	1247	19	37

Figure 1 - Low-Cycle Fatigue Strength[a] at Room Temperature



[a]Pull/pull tests with 5 ksi (34 MPa) base stress.

Room-Temperature Mechanical Properties (continued)

Table 7 - Effect of Percent Cold Work on Tensile Properties of Annealed Material

Percent Reduction	ASTM Grain Size	Yield Strength (0.2% Offset)		Tensile Strength		Elongation	Hardness
		ksi	MPa	ksi	MPa	%	%
5	9	81.7	563	138.0	952	46	99
10	9	67.0	462	132.8	916	48	96
15	9	69.3	478	135.0	931	48	97
20	9	76.1	525	140.9	972	46	97
30	10	76.4	527	141.2	974	42	98
40	10	76.7	529	141.0	972	42	98
50	10	79.0	545	147.5	1017	40	98

Table 8 - Tensile Properties for Two Annealing Temperatures

Time	1750°F (955°C)					1850°F (1010°C)				
	Yield Strength (0.2% offset)		Tensile Strength		Elongation	Yield Strength (0.2% offset)		Tensile Strength		Elongation
min	ksi	MPa	ksi	MPa	%	ksi	MPa	ksi	MPa	%
15	68.0	469	129.7	894	50	-	-	-	-	-
30	67.1	463	129.2	891	50	68.7	474	133.3	919	52
60	67.1	463	129.1	890	49	62.1	428	126.2	870	52
120	65.5	452	129.4	892	50	61.9	427	126.2	870	51

Table 9 - Effect of 2150°F (1180°C)/5 Minutes/AC Anneal on Annealed and Annealed-Plus-Aged Room-Temperature Properties

Condition	Yield Strength (0.2% Offset)		Tensile Strength		Elongation	ASTM Grain Size	Hardness
	ksi	MPa	ksi	MPa	%		Rb
As Annealed	46.3	319	111.6	767	63	5.5	84
Annealed + 1200°F (650°C)/100 h/AC	68.0	469	125.1	863	55	5.0	24c
Annealed + 1400°F (760°C)/100 h/AC	56.5	390	121.3	836	50	5.0	95

Table 10 - Effect of 1950°F (1070°C)/5 Minutes/AC Anneal on Annealed and Annealed-Plus-Aged Room-Temperature Properties

Condition	Yield Strength (0.2% Offset)		Tensile Strength		Elongation	ASTM Grain Size	Hardness
	ksi	MPa	ksi	MPa	%		Rb
As Annealed	77.6	535	138.8	957	45	9.5	96
Annealed + 1200°F (650°C)/100 h/AC	121.2	836	151.0	1041	31	9.5	100
Annealed + 1400°F (760°C)/100 h/AC	88.3	609	146.8	1012	36	9.0	96

High Temperature Mechanical Properties

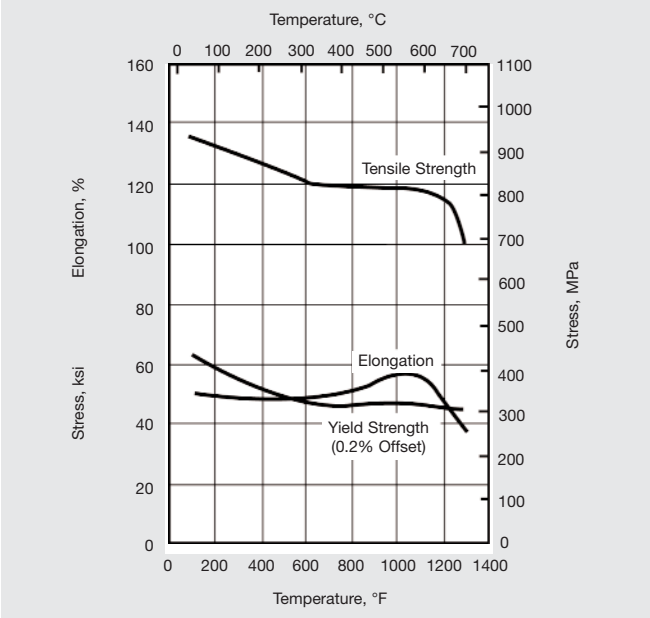
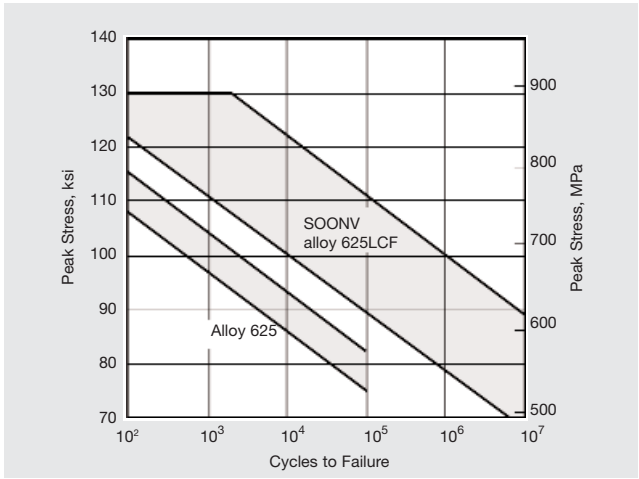


Figure 2 - High-Temperature Tensile Properties of Annealed Sheet



[a] Pull/pull tests with 5 ksi (34 MPa) base stress.

Figure 3 - Ranges of low-cycle fatigue strength[a] obtainable with SOONV alloy 625LCF and alloy 625 at temperatures of 900 - 1200°F (480 - 650°C)

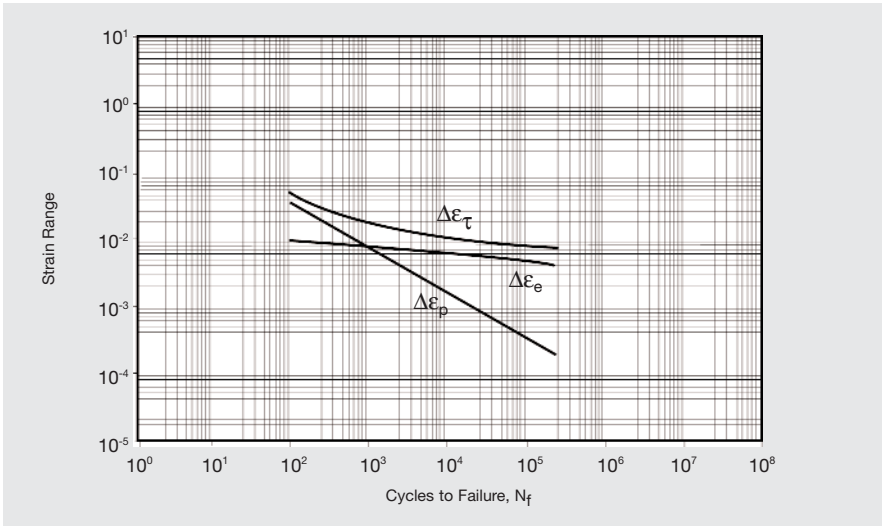


Figure 4 - Strain range vs. N_f for SOONV alloy 625LCF at 1000°F (538°C)

High Temperature Mechanical Properties (continued)

Table 11 - Effect of High-Temperature Exposure on Low-Cycle Fatigue Strength[a] at 1100°F (595°C) (ASTM Grain Size 9.5)

Peak Stress		Cycles to Failure			
ksi	MPa	As Annealed	Annealed Plus 1100°F (595°C)/300 h	Annealed Plus 1200°F (650°C)/300 h	Annealed Plus 1300°F (705°C))/300 h
120	827	600	-	-	-
110	758	7000	10,100	183,400	18,800
100	690	14,500	69,928	-	99,000
90	621	300,000	>10,000,000	-	>10,000,000
80	552	1,900,000	>10,000,000	-	>10,000,000
70	483	>10,000,000	-	-	-

[a]Pull/pull tests with 5 ksi (34 MPa) base stress

Table 12 - Effect of Cold Work and Cold Work Plus Age on LCF Properties at 1100°F (595°C) (ASTM Grain Size 9.5)

Peak Stress		Cycles to Failure		
ksi	MPa	Annealed 5%	Cold Work	5% Cold Work Plus 1100°F (595°C)/300 h
140	965	-	4700	-
130	896	-	5300	-
120	827	600	>10,000,000	14,100
110	758	7000	-	101,600
100	690	14,500	-	5,637,500
90	621	300,000	-	>10,000,000

Table 13 - ASTM Grain Size Numbers for Various Annealing Temperatures on Cold-Rolled Sheet

Time (min)	1750°F (954°C)	1800°F (982°C)	1850°F (1010°C)	1900°F (1038°C)
15	8.5	8.0	7.5	6.5
30	8.5	7.75	7.0	6.5
45	8.0	7.25	6.5	6.0
60	8.0	7.25	6.5	5.5
120	7.0	6.5	6.0	5.0

Table 14 - Effect of 300 Hr High-Temperature Exposures on Tensile Properties[a]

Exposure Temperature		Test Temperature		Yield Strength (0.2% Offset)		Tensile Strength		Elongation
°F	°C	°F	°C	ksi	MPa	ksi	MPa	%
As Annealed		70	20	67.8	467	122.7	846	45
		110	595	50.6	349	103.3	712	42
		1300	705	46.7	322	93.8	647	57
1100	595	70	20	102.3	705	162.6	1121	30
		1100	595	69.3	478	123.1	849	31
		1200	650	65.7	453	124.4	848	34
1200	650	70	20	115.6	797	174.5	1203	27
		1100	595	95.7	660	137.5	948	23
		1200	650	95.5	658	140.8	971	22

[a]All tests were in the transverse direction. ASTM grain size, 8.5.

High Temperature Mechanical Properties (continued)

Table 15 - Stress-Rupture Life for Annealed and Annealed-Plus-Aged Sheet at 1100°F (595°C), in Hours

Exposure Temperature and Time	Stress					
	80 ksi (552 MPa)	Elongation %	90 ksi (621 MPa)	Elongation %	100 ksi (690 MPa)	Elongation %
As annealed	-	-	446.0	24	4.0	30
Annealed+1100°F(595°C)/300 h	482.0	30	499.0	32	26.9	27

Table 16 - Stress-Rupture Life for Annealed and Annealed-Plus-Aged Sheet at 1200°F (650°C), in Hours

Exposure Temperature and Time	Stress					
	80 ksi (552 MPa)	Elongation %	90 ksi (621 MPa)	Elongation %	100 ksi (690 MPa)	Elongation %
As annealed	90.6	59	5.2	58	1.0	93
Annealed+1100°F(595°C)/300 h	45.7	31	22.6	36	6.7	34
Annealed+1200°F(650°C)/300 h	137.0	21	50.6	19	1.9	24

Table 17 - Stress-Rupture Life for Annealed and Annealed-Plus-Aged Sheet at 1300°F (705°C), in Hours

Exposure Temperature and Time	Stress					
	60 ksi (414 MPa)	Elongation %	70 ksi (483 MPa)	Elongation %	80 ksi (552 MPa)	Elongation %
As annealed	16.3	37	1.4	47	0.7	59
Annealed+1100°F(595°C)/300 h	16.4	37	-	-	1.0	38

Table 18 - Effect of 5% Cold Work on Stress-Rupture Properties of Annealed and Annealed-Plus-Aged Sheet at 1300°F (705°C). Stress-Rupture Life in Hours

Exposure Temperature and Time	Stress							
	50 ksi (345 MPa)	Elongation %	60 ksi (414 MPa)	Elongation %	70 ksi (483 MPa)	Elongation %	80 ksi (552 MPa)	Elongation %
As annealed	128.9	18	50.0	19	22.9	59	7.9	20
Annealed + 1300°F (705°C)/300 h	76.1	19	24.7	28	9.1	38	3.1	17

Corrosion Resistance

SOONV alloy 625LCF (UNS N06626) has the same excellent corrosion resistance as SOONV alloy 625 (UNS N06625). In mild environments such as the atmosphere, fresh and sea water, neutral salts and alkaline media, the alloy is virtually unaffected.

In more severe environments, the combination of nickel and chromium provides resistance to oxidizing chemicals and atmospheres, and the high nickel and molybdenum supply resistance to non-oxidating environments.

Welding

Table 19 - Recommended Welding Products

Shielded Metal Arc Welding	Gas Tungsten Arc Welding, Gas Metal Arc Welding
SOONV welding electrode 112	SOONV filler metal 625

Heat Treatments

SOONV alloy 625LCF is typically annealed at 1800°F (980°C) for 5 minutes with air cooling.

Available Products

SOONV alloy 625LCF is available as cold-rolled, annealed sheet and strip in thicknesses from 0.005 - 0.100 in (0.13 - 2.54 mm). Widths up to 48 in (1220 mm) are available in flat, cut lengths or as coils up to 20,000 lb (9000 kg).

Specifications

SOONV alloy 625LCF is designated as UNS N06626 and W. Nr. 2.4856, and meets the requirements for UNS N06625.

Sheet and strip- SAE AMS 5879, ASTM B 443, ASME SB 443, BS 3072 (NA21), ASME Code Case 2276.