SOONV® alloy 90 (UNS N07090/W. Nr. 2.4632) is a wrought nickel-chromium-cobalt base alloy strengthened by additions of titanium and aluminum. It has been developed as an age-hardenable creep-resisting alloy for service at temperatures up to 920°C (1688°F.

The alloy is used for turbine blades, discs, forgings, ring sections and hot-working tools.

Composition, %

Carbon	0.13 max.
Silicon	1.0 max.
Copper	0.2 max.
Iron	1.5 max.
Manganese	1.0 max.
Chromium	18.0-21.0
Titanium	2.0-3.0
Aluminum	1.0-2.0
Cobalt	15.0-21.0
Boron	0.02 max.
Sulfur	0.015 max.
Lead	0.0020 max.
Zirconium	0.15 max.
Nickel	Balance

Heat Treatment

The heat treatments recommended are as follows:

Bar 8 h/1080°C(1975°F)/AC + 16 h/700°C (1290°F)/AC

Sheet 3 min/1150°C(2100°F)/FBQ or WQ + 1 h/925°C(1700°F)/AC + 4 h/750°C (1380°F)/AC

Welded sheet 3 min/1150°C(2100°F)/FBQ or WQ + weld + 1 h/925°C(1700°F)/AC + 4 h/750°C(1380°F)/AC

Interstage anneal of sheet 20 min/1040°C (1900°F)/AC or WQ

The data for sheet have been obtained from material given a second stage interstage anneal (20 min/1040°C(1900°F)/AC), which is purely a softening treatment. Improved tensile and rupture ductility can be achieved by using 1 h/925°C(1700°F)/AC as the second stage heat treatment.

Physical Properties

Density, Mg/m^3	8.18
lb/in^3	0.296
Melting Range	
Liquidus temperature, °C	1370
°F	2500
Solidus temperature, °C	1310
°F	2390

The density has been determined on extruded bar, extruded bar subsequently forged and extruded section subsequently cold rolled given a heat treatment of 8 h/1080°C (1975°F)/AC + 16 h/700°C (1290°F)/AC.

Table 1 - Specific Heat

Temperature		Specific Heat	
°C	°F	J/kg•°C	Btu/lb•°F
20	68	446	0.11
100	212	467	0.11
200	392	494	0.12
300	572	520	0.12
400	752	547	0.13
500	932	572	0.14
600	1112	600	0.14
700	1292	626	0.15
800	1472	652	0.16
900	1652	679	0.16
1000	1832	706	0.17

Table 2 - Thermal Conductivity

Temperature, °C		Thermal Conductivity	
°C	°F	W/m•°C	Btu•in/ft²•h•°F
20	68	11.47	80.46
100	212	12.77	89.58
200	392	14.44	101.30
300	572	15.99	112.17
400	752	17.54	123.04
500	932	18.97	133.07
600	1112	20.64	144.79
700	1292	22.32	156.57
800	1472	23.99	168.29
900	1652	25.83	181.20
1000	1832	27.88	195.58

Calculated from electrical resistance measurements.
Cold rolled sheet heat-treated 2-3 min/1150°C(2100°F)/FBQ + 20 min/1040°C(1900°F)/AC + 4 h 750°C(1380°F)/ AC.

Table 3 - Mean Coefficient of Linear Thermal Expansion

Temperature Range		Coefficient of Expansion	
°C	°F	µm/m °C	in/in °F x 10^{-6}
20-100	68-212	12.7	7.1
20-200	68-392	13.3	7.4
20-300	68-572	13.7	7.6
20-400	68-752	14.0	7.8
20-500	68-932	14.3	7.9
20-600	68-1112	14.8	8.2
20-700	68-1292	15.3	8.5
20-800	68-1472	16.2	9.0
20-900	68-1652	17.1	9.5
20-1000	68-1832	18.2	10.1

Extruded section subsequently cold rolled from 5 casts given heat treatment 8 h/1080°C(1975°F)/AC + 16 h/700°C(1290°F)/AC.

Table 4 - Electrical Properties

Electrical Resistivity at 20°C = 1.18 µohm•m (710 ohm•circ•mil/ft)	
°C (°F)	Relative Resistance
20 (68)	1.000
100 (212)	1.025
200 (392)	1.042
300 (572)	1.068
400 (752)	1.085
500 (932)	1.110
600 (1112)	1.110
700 (1292)	1.110
800 (1472)	1.110
900 (1652)	1.102
1000 (1832)	1.085

Cold rolled sheet from 5 casts given heat treatment 2-3 min/1150°C(2100°F)/FBQ + 20 min/1040°C(1900°F)/AC + 4 h/750°C(1380°F)/AC.

Table 5 - Magnetic Properties

Mass susceptibility at 1000 oersted:	2.25 x 10^{-4} cm^3/g
Volume susceptibility at 1000 oersted:	1.82 x 10^{-3}
Magnetic Permeability at:	
300	1.0706
500	1.0440
1000	1.0231
1500	1.0163
2000	1.0130
2500	1.0085
3000	1.0073

Cold rolled sheet from 5 casts given heat treatment 2-3 min/1150°C(2100°F)/FBQ + 20 min/1040°C(1900°F)/AC + 4 h/750°C(1380°F)/AC.

Table 6 - Dynamic Young's Modulus of Extruded Bar

Temperature		Extruded Bar[1]		Extruded Bar[2] Subsequently Forged		Extruded Section[3] Subsequently Cold Rolled	
°C	°F	GPa	10^3 ksi	GPa	10^3 ksi	GPa	10^3 ksi
20	68	204	30	226	33	222	32
100	212	199	29	221	32	219	32
200	392	194	28	216	31	214	31
300	572	188	27	208	30	208	30
400	752	181	26	201	29	200	29
500	932	174	25	194	28	193	28
600	1112	168	24	186	27	185	27
700	1292	159	23	177	26	177	26
800	1472	150	22	167	24	166	24
900	1652	137	20	155	23	154	22
1000	1832	125	18	141	20	140	20

Results were obtained on material from (1) 8 casts (2) 14 casts and (3) 5 casts given heat treatment 8 h/1080°C(1975°F)/AC + 16 h/700°C(1290°F)/AC.

Table 7 - Dynamic Young's and Torsional Moduli of Cold Rolled Sheet

Temperature		Dynamic Young's Modulus		Dynamic Torsional Modulus	
°C	°F	GPa	10^3 ksi	GPa	10^3 ksi
20	68	220	32	83	12
100	212	216	31	82	12
200	392	210	31	80	12
300	572	204	30	77	11
400	752	197	29	74	11
500	932	191	28	71	10
600	1112	184	27	68	10
700	1292	176	26	65	9
800	1472	168	24	61	9
900	1652	155	23	57	8
1000	1832	142	21	51	7

Cold rolled sheet from 5 casts given heat treatment 2-3 min/1150°C(2100°F)/FBQ + 20 min/1040°C(1900°F)/AC + 4 h/750°C(1380°F)/AC.

Tensile Properties

Table 8 - Tensile Properties of Extruded Bar

Heat treatment 8 h/1080°C(1975°F)/AC + 16 h/700°C(1290°F)/AC									
Temperature		0.1% Proof Stress		0.2% Proof Stress		Tensile Strength		Elongation on 5.65	Reduction of Area,
°C	°F	MPa	10^3 ksi	MPa	10^3 ksi	MPa	10^3 ksi	√So, %	%
20	68	729	106	752	109	1175	170	30	47
100	212	723	105	742	108	1148	167	27	46
200	392	689	100	708	103	1111	161	28	46
300	572	664	96	681	99	1087	158	29	48
400	752	661	96	678	98	1081	157	32	49
500	932	657	95	672	98	1038	151	31	49
600	1112	657	95	675	98	1027	149	26	47
700	1292	621	90	640	93	899	130	18	28
800	1472	510	74	532	77	657	95	18	26
900	1652	288	42	306	44	349	51	30	51
1000	1832	45	7	48	7	76	11	130	99

Average results of tests on 9 casts. Strain rate 0.005/min to proof stress (at room temperature), 0.002/min to proof stress (at elevated temperatures) and 0.1/min thereafter.

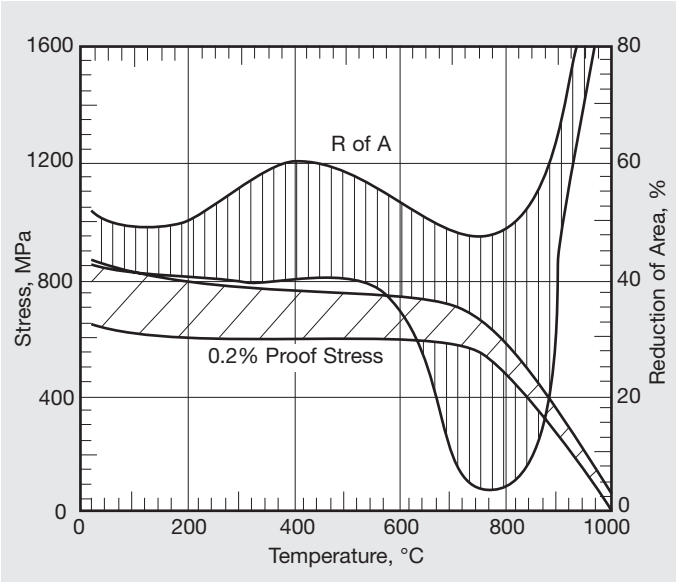


Figure 1. Tensile properties of extruded bar. Heat treatment 8 h/1080°C (1975°F) /AC + 16 h/700°C (1290°F)/AC.

98% confidence region calculated on 9 casts.

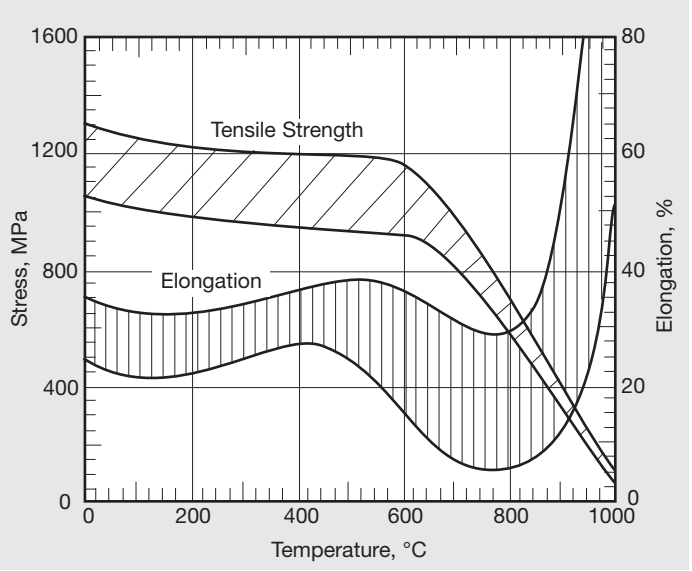


Figure 2. Tensile properties of extruded bar. Heat treatment 8 h/1080°C(1975°F)/AC + 16 h/700°C(1290°F)/AC.

98% confidence region calculated on 9 casts.

Table 9 - Tensile Properties of Extruded Bar Subsequently Forged

Heat treatment 8 h/1080°C(1975°F)/AC + 16 h/700°C(1290°F)/AC

Temperature °C	Temperature °F	0.1% Proof Stress MPa	0.1% Proof Stress 10^3 ksi	0.2% Proof Stress MPa	0.2% Proof Stress 10^3 ksi	Tensile Strength MPa	Tensile Strength 10^3 ksi	Elongation on 5.65 √So, %	Reduction of Area %
20	68	791	115	813	117	1251	181	28	41
100	212	757	110	777	113	1202	174	26	42
200	392	732	106	751	109	1175	170	26	42
300	572	715	104	734	107	1169	170	28	43
400	752	715	104	732	106	1148	167	28	44
500	932	706	102	726	105	1120	162	28	43
600	1112	698	101	723	105	1092	158	23	39
700	1292	690	100	711	103	965	140	13	17
800	1472	551	80	573	83	683	99	10	16
900	1652	284	41	300	44	346	50	21	37
1000	1832	45	7	48	7	76	11	77	97

Average results of tests on 15 casts. Strain rate 0.005/min to proof stress (at room temperature), 0.002/min to proof stress (at elevated temperatures) and 0.1/min thereafter.

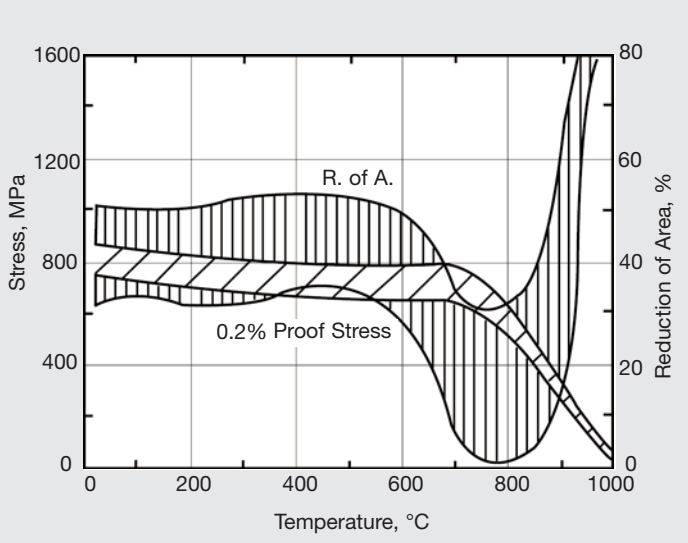


Figure 3. Tensile properties of extruded bar subsequently forged.
Heat treatment 8 h/1080°C(1975°F)/AC + 16 h/700°C(1290°F)/AC.
98% confidence region calculated on 15 casts.

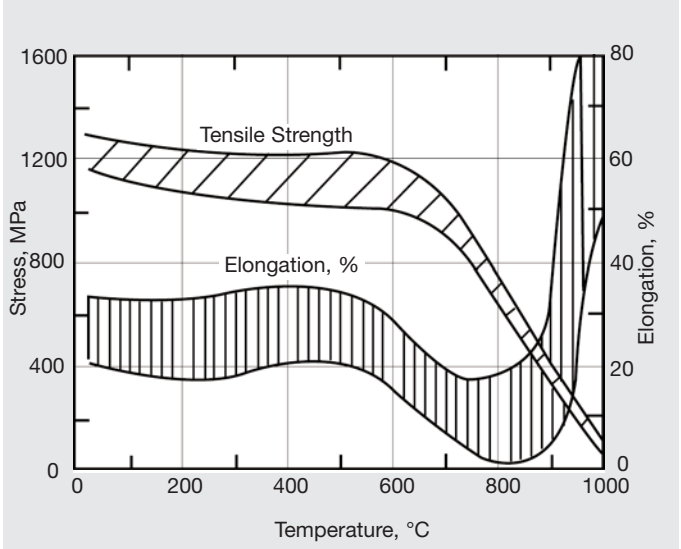


Figure 4. Tensile properties of extruded bar. subsequently forged.
Heat treatment 8 h/1080°C(1975°F)/AC + 16 h/700°C(1290°F)/AC.
98% confidence region calculated on 15 casts.

Table 10 - Tensile Properties of Extruded Section Subsequently Cold Rolled

Heat treatment 8 h/1080°C(1975°F)/AC + 16 h/700°C(1290°F)/AC

Temperature °C	Temperature °F	0.1% Proof Stress MPa	0.1% Proof Stress 10^3 ksi	0.2% Proof Stress MPa	0.2% Proof Stress 10^3 ksi	Tensile Strength MPa	Tensile Strength 10^3 ksi	Elongation on 5.65 √So, %	Reduction of Area %
20	68	813	118	831	121	1265	183	30	45
100	212	791	115	813	118	1233	179	28	43
200	392	762	110	777	113	1203	174	29	45
300	572	742	108	760	110	1203	174	30	45
400	752	732	106	748	109	1189	172	33	44
500	932	726	105	745	108	1134	164	29	41
600	1112	717	104	748	109	1135	165	25	41
700	1292	703	102	722	105	986	143	22	22
800	1472	573	83	598	87	717	104	23	26
900	1652	332	48	349	51	388	56	34	46
1000	1832	50	7	54	8	91	13	132	97

Average results of tests on 5 casts. Strain rate 0.005/min to proof stress (at room temperature), 0.002/min to proof stress (at elevated temperatures) and 0.1/min thereafter.

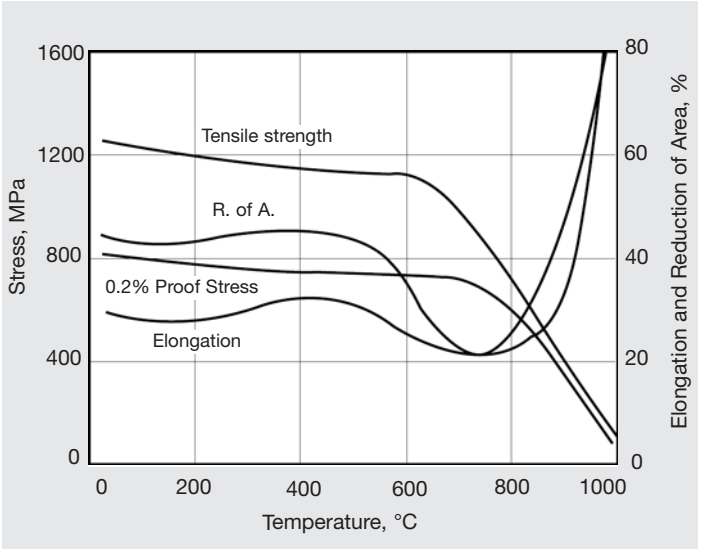


Figure 5. Tensile properties of extruded section subsequently cold rolled. Heat treatment 8 h/1080°C(1975°F)/AC + 16 h/700°C(1290°F)/AC.

Table 11 - Tensile Properties of Cold Rolled Sheet

Heat treatment 2-3 min/1150°C(2102°F)/FBQ + 20 min/1040°C(1904°F)/AC + 4 h/750°C(1382°F)/AC

Temperature °C	Temperature °F	0.1% Proof Stress MPa	0.1% Proof Stress 10^3 ksi	0.2% Proof Stress MPa	0.2% Proof Stress 10^3 ksi	Tensile Strength MPa	Tensile Strength 10^3 ksi	Elongation on 50 mm %
20	68	808	117	831	121	1180	171	23
100	212	764	111	791	115	1138	165	24
200	392	754	109	780	113	1104	160	26
300	572	741	107	754	109	1072	155	27
400	752	734	106	754	109	1038	151	28
500	932	717	104	740	107	995	144	30
600	1112	701	102	729	106	961	139	23
700	1292	680	99	703	102	848	123	8
800	1472	505	73	548	79	669	97	6
900	1652	272	39	289	42	346	50	16
1000	1832	57	8	62	9	83	12	66

Average results of tests on 5 casts 0.6-2.0 mm thick. Strain rate 0.005/min to proof stress (at room temperature), 0.002/min to proof stress (at elevated temperatures) and 0.1/min thereafter.

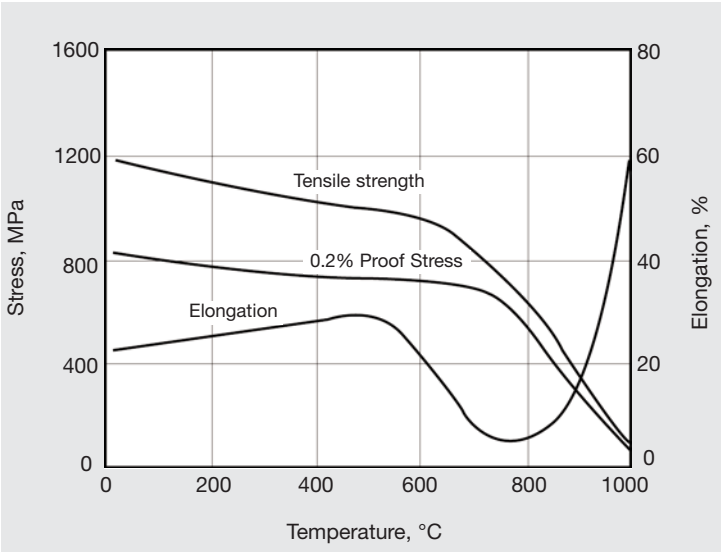


Figure 6. Tensile properties of cold rolled sheet.

Heat treatment 2-3 min/1150°C(2102°F)/FBQ + 20 min/1040°C(1904°F)/AC + 4 h/750°C(1382°F)/AC.

Table 12 - Tensile Properties of Cold Rolled Sheet, Welded

Heat treatment 2-3 min/1150°C(2102°F)/FBQ + weld + 20 min/1040°C(1904°F)/AC + 4 h/750°C(1382°F)/AC								
Temperature		0.1% Proof Stress		0.2% Proof Stress		Tensile Strength		Elongation on 50 mm
°C	°F	MPa	10^3 ksi	MPa	10^3 ksi	MPa	10^3 ksi	%
20	68	752	109	794	115	1115	162	17
100	212	754	109	788	114	1106	160	19
200	392	722	105	752	109	1067	155	19
300	572	695	101	731	106	1021	148	19
400	752	703	102	729	106	999	145	19
500	932	681	99	714	104	956	139	19
600	1112	680	99	709	103	925	134	13
700	1292	680	99	714	104	820	119	4
800	1472	538	78	563	82	604	88	2
900	1652	291	42	312	45	357	52	7
1000	1832	54	8	62	9	96	14	46

Average results of tests on 5 casts 0.6-2.0 mm thick. Strain rate 0.005/min to proof stress (at room temperature), 0.002/min to proof stress (at elevated temperatures) and 0.1/min thereafter.

Creep Properties

The creep characteristics of SOONV alloy 90 have been determined on bar (15 casts) and sheet (1 cast). Total plastic strain has been determined on extruded section (1 cast) and sheet (1 cast).

Creep-rupture properties for SOONV alloy 90 extruded bar subsequently forged are shown in Table 13 and Figures 7 and 8 by Larson-Miller presentation and Graham and Walles* technique.

Creep-rupture properties for SOONV alloy 90 cold-rolled sheet are shown in Table 14 and Figures 7 and 9 also by Larson-Miller presentation and Graham and Walles technique.

Derived total plastic strain data for extruded section subsequently cold rolled and cold-rolled sheet are shown in Tables 15 and 16. Test specimens were 9.1-11.7 mm diameter x 76 mm gauge length.

*The Graham and Walles technique assumes that stress-time test points fall on the continuous series of straight lines for each temperature, with slopes 1/32, 1/16, 1/8, 1/4, 1/2, the change of slope and the distance between lines being dependent on a time/temperature relationship. A general description of the Graham and Walles analysis can be found in 'Regularities in Creep and Hot Fatigue Data', Parts 1 and 2, Aero Research Council T.R. CP379 and 380, 1958, London H.M.S.O.

Note: It is implicit in the Larson-Miller presentation that no indication is given regarding test temperatures and range of rupture lives covered. Tables 13 and 14 show the temperature ranges and rupture lives used to establish the published curves. These tables should be referred to before using the curves, since excessive extrapolation in time and temperature is not recommended.

Despite these qualifications, it must be most strongly emphasized that all data given in this section are typical. No attempt has been made to indicate the scatter that may result from slight processing or compositional variables. Statistical

Table 13 - Creep Rupture Properties of Extruded Bar Subsequently Forged

Heat treatment 8 h/1080°C(1975°F)/AC + 16 h/700°C(1290°F)/AC

Test temperature °C	°F		Stress to produce rupture in 100 h MPa	100 h 10^3 ksi	300 h MPa	300 h 10^3 ksi	1000 h MPa	1000 h 10^3 ksi	3000 h MPa	3000 h 10^3 ksi	10000 h MPa	10000 h 10^3 ksi	Elongation at fracture on 5.65 √So %
700	1292	GW	556	81	487	71	417	60	332	48	(248)	(36)	2-5
		LM	510	74	456	66	402	58	348	50	(294)	(43)	
750	1382	GW	386	56	340	49	275	40	209	30	(152)	(22)	3-7
		LM	379	55	332	48	278	40	232	34	(186)	(27)	
815	1499	GW	248	36	186	27	139	20	(105)	(15)	–	–	5-7
		LM	240	35	193	28	155	22	(124)	(18)	–	–	
870	1598	GW	133	19	101	15	(74)	(11)	–	–	–	–	6-12
		LM	139	20	109	16	(77)	(11)	–	–	–	–	

Average results of tests on 15 casts.
GW= Graham & Walles analysis. LM= Larson-Miller analysis. ( )= outside range of determination.

Table 14 - Creep Rupture Properties of Cold Rolled Sheet

Heat treatment 2 min/1150°C(2102°F)/WQ + 4 h/750°C(1382°F)/AC

Test temperature °C	°F	Stress to produce rupture in 50 h MPa	50 h 10^3 ksi	100 h MPa	100 h 10^3 ksi	300 h MPa	300 h 10^3 ksi	1000 h MPa	1000 h 10^3 ksi	3000 h MPa	3000 h 10^3 ksi	Elongation at fracture on 50 mm %
700	1292	464	67	428	62	371	54	320	46	271	39	0.3-0.6
750	1382	349	51	320	46	275	40	221	32	170	25	0.5-1.1
800	1499	244	35	218	32	164	24	104	15	59	9	1.4-3.3
850	1562	163	24	136	20	95	14	54	8	29	4	2.6-6.8
900	1652	90	13	74	11	48	7	26	4	–	–	4.0-8.5

Results of tests from 1 cast 1.6 mm thick.

Figure 7. Creep rupture properties. Before using this curve to derive information, your attention is drawn to the note on page 7.

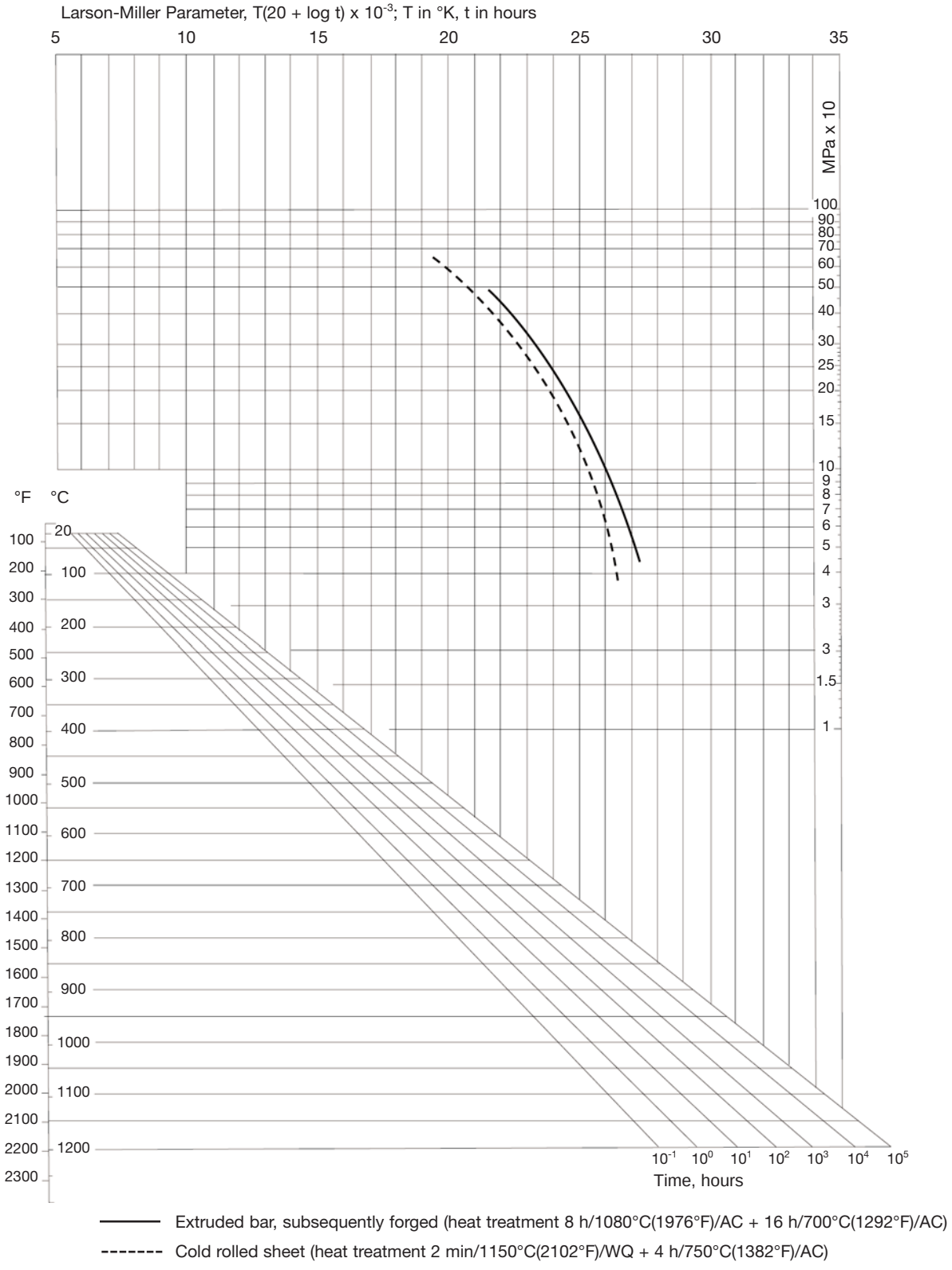


Figure 8. Creep rupture properties of extruded bar, subsequently forged.
Heat treatment 8 h/1080°C(1976°F)/AC + 16 h/700°C(1292°F)/AC

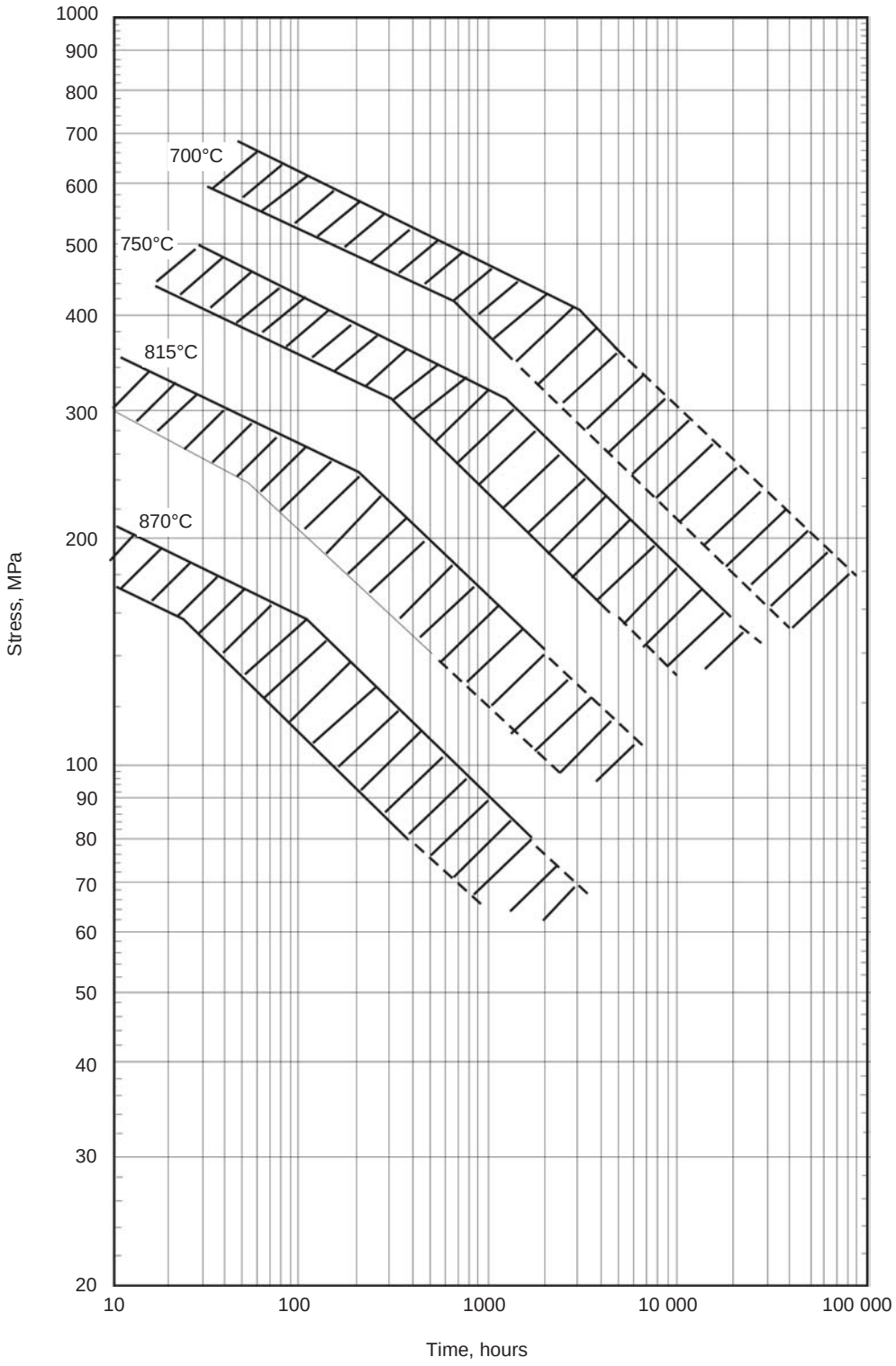


Figure 9. Creep rupture properties of cold rolled sheet.
Heat treatment 2 min/1150°C(2102°F)/WQ + 4 h/750°C(1382°F)/AC

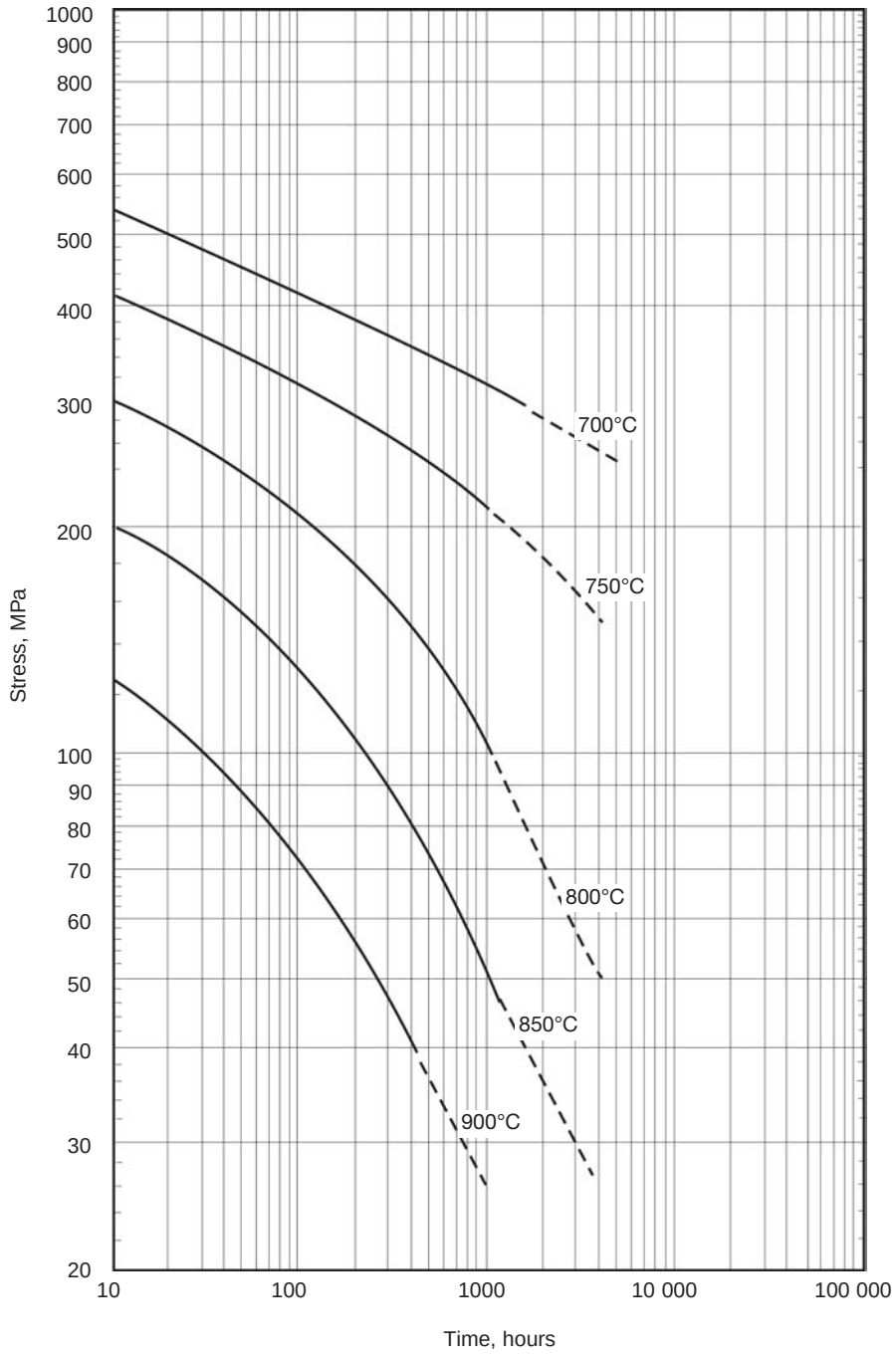


Table 15 - Total Plastic Strain Data for Extruded Section Subsequently Cold Rolled

Heat treatment 8 h/1080°C(1975°F)/AC + 16 h/700°C(1290°F)/AC

Test temperature °C	°F	Strain %	Stress to give total plastic strain in											
			100 h		300 h		1000 h		3000 h		10000 h		30000 h	
			MPa	10^3 ksi	MPa	10^3 ksi	MPa	10^3 ksi	MPa	10^3 ksi	MPa	10^3 ksi	MPa	10^3 ksi
600	1112	0.1	592	86	538	78	481	70	427	62	368	53	–	–
		0.2	646	94	592	86	533	77	481	70	–	–	–	–
		0.5	–	–	649	94	578	84	516	75	(448)	(65)	–	–
650	1202	0.1	444	64	397	58	346	50	300	44	(249)	(36)	–	–
		0.2	499	72	453	66	403	58	359	52	309	45	–	–
		0.5	529	77	485	70	434	63	386	56	336	49	(288)	(42)
700	1292	0.1	371	54	322	47	277	40	221	32	167	24	–	–
		0.2	430	62	379	55	322	47	269	39	210	30	158	23
		0.5	479	69	430	62	362	52	300	44	231	33	183	27
750	1382	0.1	232	34	186	27	138	20	98	14	65	9	–	–
		0.2	269	39	223	32	175	25	130	19	85	12	40	6
		0.5	300	44	255	37	206	30	161	23	112	16	68	10
815	1499	0.1	119	17	85	12	57	8	39	6	(28)	(4)	–	–
		0.2	143	21	109	16	77	11	56	8	31	4	–	–
		0.5	169	25	132	19	93	13	62	9	39	6	–	–
870	1598	0.1	73	11	50	7	29	4	22	3	(16)	(2)	–	–
		0.2	84	12	60	9	37	5	25	4	(17)	(3)	–	–
		0.5	96	14	73	10	46	7	31	4	19	3	–	–

Results of tests on 1 cast 1.6 mm thick. ( )= outside range of determination.

Table 16 - Total Plastic Strain Data for Cold Rolled Sheet

Heat treatment 2 min/1150°C(2102°F)/WQ + 4 h/750°C(1382°F)/AC

Test temperature °C	°F	Strain %	Stress to give total plastic strain in							
			50 h		100 h		300 h		1000 h	
			MPa	10^3 ksi	MPa	10^3 ksi	MPa	10^3 ksi	MPa	10^3 ksi
700	1292	0.1	353	51	320	46	269	39	210	30
		0.2	420	61	388	56	336	49	269	39
750	1382	0.1	241	35	209	30	155	22	99	14
		0.2	289	42	258	37	206	30	139	20
800	1472	0.1	138	20	113	16	76	11	46	7
		0.2	178	26	149	22	105	15	63	9
850	1562	0.1	74	11	57	8	37	5	22	3
		0.2	99	14	80	12	51	7	29	4
900	1652	0.1	39	6	29	4	17	2	–	–
		0.2	53	8	42	6	25	4	–	–

Results of tests from 1 cast.

Fatigue Properties

Fatigue properties for SOONV alloy 90 have been determined on extruded bar subsequently hot rolled (tensile-compressive and rotating bend) and cold rolled sheet (alternating direct stress).

Gerber Diagrams

Figures 10 to 12 illustrate the fatigue properties of SOONV alloy 90 extruded bar subsequently hot rolled (heat treatment 8 h/1080°C(1976°F)/AC+16 h/700°C (1292°F)/AC) at 600°C(1112°F), 815°C(1499°F) and 870°C(1598°F) respectively, under conditions of uniaxial stressing with varying mean stress. The abscissae represent the mean stress and the ordinate fluctuating stress. Thus a point on the horizontal axis represents the steady stress which will produce fracture in a specific time in a normal creep rupture test. A point on the vertical axis indicates the fluctuating stress required to produce a pure fatigue failure in the same time at the particular testing frequency adopted. The lines radiating from the origin correspond to stress conditions of the form P ± CP where P is the steady stress and C is a constant for any line. The full lines join points corresponding to lines of 100, 300 and 1000 hours for varying stress conditions.

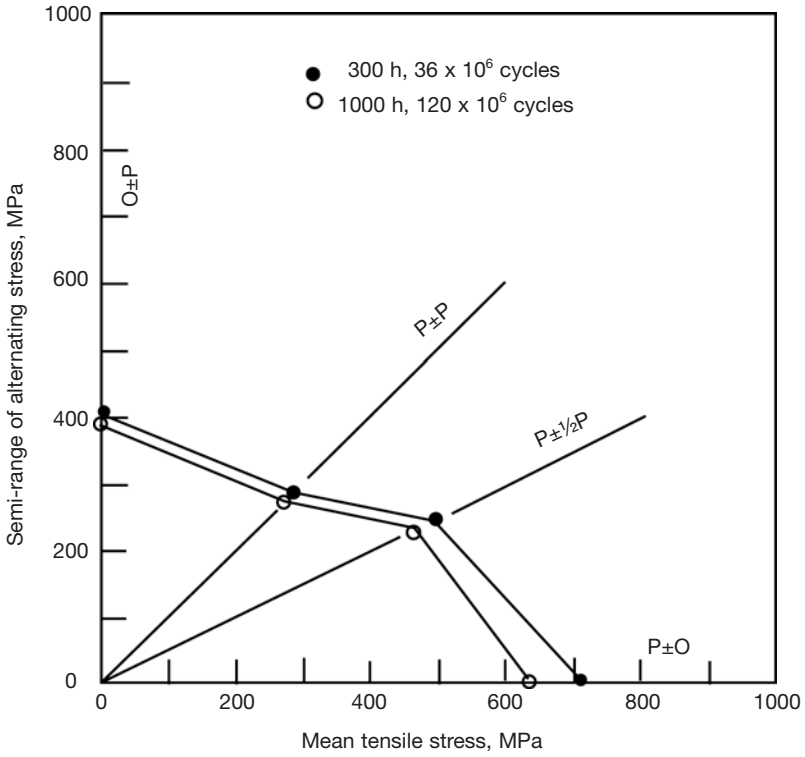
Table 17 - Tensile-Compressive Properties of Extruded Bar, Subsequently Hot Rolled

Heat treatment 8 h/1080°C(1975°F)/AC + 16 h/700°C(1290°F)/AC

Test temperature °C	°F	Stress Form	Stress (P) for lives of 100 h (12 x 10^6 cycles) MPa	10^3 ksi	300 h (36 x 10^6 cycles) MPa	10^3 ksi	1000 h (120 x 10^6 cycles) MPa	10^3 ksi
600	1112	O±P	–	–	402	58	396	57
		P±P	–	–	283	41	278	40
		P±½P	–	–	491	71	464	67
		P±O	–	–	711	103	634	92
700	1292	O±P	–	–	297	43	278	40
750	1382	O±P	–	–	258	37	237	34
815	1499	O±P	238	35	207	30	172	25
		P±P	146	21	113	16	78	11
		P±½P	161	23	122	18	82	12
		P±⅜P	163	24	129	19	92	13
		P±¼P	180	26	135	20	85	12
		P±O	204	30	161	23	113	16
870	1598	O±P	175	25	143	21	107	16
		P±P	78	11	53	8	31	4
		P±½P	96	14	71	10	42	6
		P±⅜P	92	13	66	10	40	6
		P±¼P	96	14	74	11	50	7
		P±O	99	14	78	11	53	8

Figure 10. Fatigue properties at 600°C (1112°F) for extruded bar subsequently hot rolled.

Heat treatment 8 h/1080°C(1976°F)/AC+16 h/700°C(1292°F)/AC



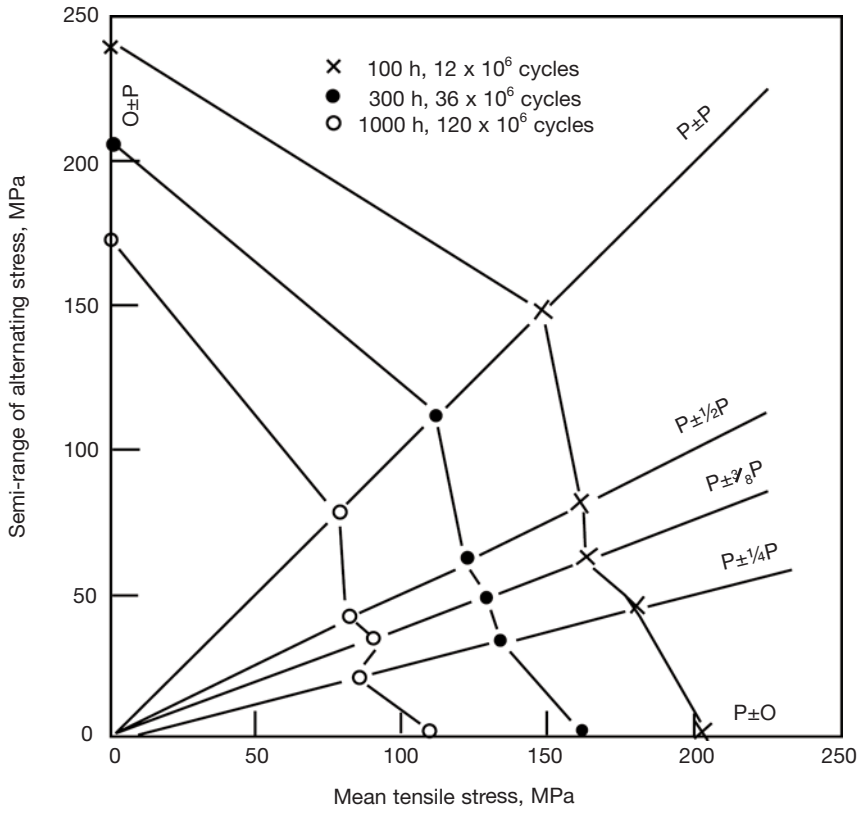


Figure 11. Fatigue properties at 815°C (1499°F) for extruded bar subsequently hot rolled.

Heat treatment 8 h/1080°C(1976°F)/AC+16 h/700°C(1292°F)/AC

Figure 12. Fatigue properties at 870°C (1598°F) for extruded bar subsequently hot rolled.

Heat treatment 8 h/1080°C(1976°F)/AC+16 h/700°C(1292°F)/AC

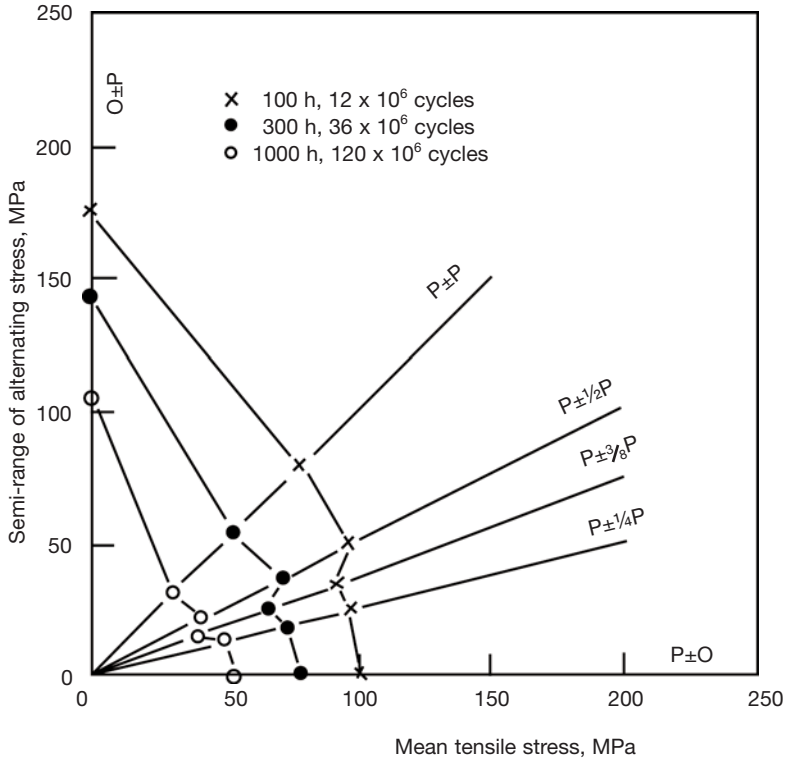


Table 18 - Rotating Bend Fatigue Properties of Extruded Bar Subsequently Hot Rolled

Heat treatment 8 h/1080°C(1975°F)/AC + 16 h/700°C(1292°F)/AC								
Test temperature		Stress Form	Stress (P) for lives of					
			100 h (15 x 10^6 cycles)		300 h (45 x 10^6 cycles)		1000 h (150 x 10^6 cycles)	
°C	°F		MPa	10^3 ksi	MPa	10^3 ksi	MPa	10^3 ksi
750	1382	O±P	417	60	386	56	353	51
815	1499	O±P	317	46	274	40	232	34
870	1598	O±P	217	31	189	27	158	23

Table 19 - Alternating Direct Stress Fatigue Properties (Mean Stress Zero) for Cold Rolled Sheet

Heat treatment 2 min/1150°C(2102°F)/WQ + 4 h/750°C(1382°F)/AC						
Test temperature		Endurance limit at 100 hours				Strength Reduction Factor
		Plain		Notched		
°C	°F	MPa	10^3 ksi	MPa	10^3 ksi	kf
20	68	317	46	113	16	2.8
500	932	271	39	113	16	2.4
700	1292	325	47	116	17	2.8
750	1382	286	41	116	17	2.5
800	1472	224	32	96	14	2.3

Results from test of 1 cast 1.6 mm thick.

Impact Data

The room temperature Charpy impact strength for SOONV alloy 90 extruded bar subsequently forged and given the heat treatment 8 h/1080°C(1976°F)/AC+16 h/700°C (1292°F)/AC is of the order 78J (57 ft•lbf).

Long term embrittlement of this alloy has been investigated by Charpy impact testing at room and elevated temperatures and the results of duplicate tests are given in Tables 20 and 21 respectively.

Charpy test specimens have square cross section of 10 mm, test area of 80 mm^2 and V-notch angle of 45°.

Table 20 - Room Temperature Impact Values, (Extruded Bar, Forged)

Soaking Time, h	Soaking Temperature									
	700°C / 1292°F		750°C / 1382°F		800°C / 1472°F		850°C / 1562°F		900°C / 1652°F	
	J	ft•lbf	J	ft•lbf	J	ft•lbf	J	ft•lbf	J	ft•lbf
30	60:61	44:45	49:49	36:36	46:47	34:35	54:57	40:42	76:64	56:47
100	60:53	44:39	46:45	34:33	43:43	32:32	54:47	40:35	65:64	48:47
300	42:39	31:29	42:42	31:31	45:45	33:33	53:47	39:35	61:60	45:44
1000	34:32	25:24	31:34	23:25	41:39	30:29	50:42	37:31	53:50	39:37
3000	29:29	21:21	32:31	24:23	37:41	27:30	43:49	32:36	43:41	32:30
10000	27:52	20:38	32:27	24:20	37:35	27:26	35:27	26:20	35:29	26:21

Table 21 - Elevated Temperature Impact Values, (Extruded Bar, Forged)

Soaking Time, h	Soaking and Test Temperature									
	700°C / 1292°F		750°C / 1382°F		800°C / 1472°F		850°C / 1562°F		900°C / 1652°F	
	J	ft•lbf	J	ft•lbf	J	ft•lbf	J	ft•lbf	J	ft•lbf
0	79:76	58:56	68:77	50:57	62:66	46:49	76:75	56:55	84:77	62:57
30	57:57	42:42	52:53	38:39	47:53	35:39	57:57	42:42	66:68	49:50
100	52:56	38:41	46:49	34:36	46:49	34:36	54:54	40:40	69:69	51:51
300	46:52	34:38	41:43	30:32	46:45	34:33	52:54	38:40	65:69	48:51
1000	38:46	28:34	42:42	31:31	45:43	33:32	54:53	40:39	64:62	47:46
3000	45:43	33:32	43:45	32:33	50:54	37:40	61:60	45:44	65:60	48:44
10000	34:35	25:26	41:41	30:30	52:57	38:42	56:57	41:42	52:50	38:37

The room temperature Charpy impact strength for SOONV alloy 90 extruded section subsequently cold rolled and given the heat treatment 8 h/1080° (1976°F)/AC+16 h/700°C (1292°F)/AC is of the order 63J.

Long term embrittlement of this alloy has been investigated by Charpy impact testing at room and elevated temperatures and the results of duplicate tests are given in Tables 22 and 23 respectively.

Charpy test specimens have square cross section of 10 mm, test area of 80 mm^2 and V-notch angle of 45°.

Table 22 - Room Temperature Impact Values, (Extruded Section, Cold Rolled)

Soaking Time, h	Soaking Temperature									
	700°C / 1292°F		750°C / 1382°F		800°C / 1472°F		850°C / 1562°F		900°C / 1652°F	
	J	ft•lbf	J	ft•lbf	J	ft•lbf	J	ft•lbf	J	ft•lbf
30	62:64 / 46:47		50:57 / 37:42		56:72 / 41:53		57:58 / 42:43		76:75 / 56:55	
100	52:58 / 38:43		46:49 / 34:36		53:65 / 39:48		56:60 / 41:44		64:66 / 47:49	
300	43:46 / 32:34		46:43 / 34:32		43:43 / 32:32		52:49 / 38:36		54 / 40	
1000	38:41 / 28:30		37:38 / 27:28		52:49 / 38:36		48:50 / 35:37		52:43 / 38:32	
3000	31:34 / 23:25		27:30 / 20:22		35:37 / 26:27		37:41 / 27:30		37:39 / 27:29	
10000	27:26 / 20:20		29:30 / 21:22		30:30 / 22:22		29:29 / 21:21		29:27 / 21:20	

Table 23 - Elevated Temperature Impact Values, (Extruded Section, Cold Rolled)

Soaking Time, h	Soaking and Test Temperature									
	700°C / 1292°F		750°C / 1382°F		800°C / 1472°F		850°C / 1562°F		900°C / 1652°F	
	J	ft•lbf	J	ft•lbf	J	ft•lbf	J	ft•lbf	J	ft•lbf
0	62:71 / 46:52		65:62 / 48:46		64:57 / 47:42		60:54 / 44:40		66:71 / 49:52	
30	58:58 / 43:43		49:48 / 36:35		45:45 / 33:33		48:49 / 35:36		60:65 / 44:48	
100	53:52 / 39:38		49 / 36		41:42 / 30:31		49:49 / 36:36		60 / 44	
300	43:68 / 32:50		48:41 / 35:30		43:43 / 32:32		48:49 / 35:36		58:56 / 43:41	
1000	39:41 / 29:30		41:41 / 30:30		45:45 / 33:33		50:48 / 37:35		57:58 / 42:43	
3000	38:39 / 28:29		38:41 / 28:30		48:45 / 35:33		52:49 / 38:36		54:50 / 40:37	
10000	35:33 / 26:24		43:43 / 32:32		48:53 / 35:39		49:49 / 36:36		45:42 / 33:31	

Corrosion Resistance

Oxidation in Air (continuous heating)

Descaled Weight loss (mg/cm^2) after 100 hours at				
800°C	900°C	950°C	1000°C	1100°C
0.46	2.52	5.50	10.40	11.23

Intermittent Heating (cooling to room temperature every 24 hours)

Descaled Weight loss (mg/cm^2) after 100 hours at				
800°C	900°C	950°C	1000°C	1100°C
–	3.02	8.12	8.18	17.7

Cyclic Heating (15 min in furnace, 5 min outside)

Tem-perature °C	Time to Onset of spalling h	Rate of spalling mg/cm^2/h	Weight change in 1000 h mg/cm^2
890	>1000	–	+2.95
910	>1000	–	+5.52
990	250	0.304	-214
1010	200	0.458	-332
1090	100	1.040	-880
1110	75	1.268	-1107

Resistance to Atmospheres Containing SO_2

Atmosphere	Descaled Weight loss (mg/cm^2) after 1000 hours at			
	600°C	700°C	800°C	900°C
3% SO_2 – Argon	3.7	18.0	40.0	–
3% SO_2 – Air	4.5	8.1	1.4	2.0
3% SO_2 – 5% O_2 – Argon	1.9	4.2	1.3	3.7

Working Instructions

Hot Working

SOONV alloy 90 should be hot worked in the range 1050-1200°C (1922-2192°F).

Cold Working

Average mechanical properties pertinent to cold forming operations for 0.6-2.0 mm thick sheet annealed 2-3 min/1150°C(2102°F)/FBQ are:

0.1% proof stress	434 MPa (63 ksi)
0.2% proof stress	461 MPa (67 ksi)
0.5% proof stress	484 MPa (70 ksi)
Tensile strength	865 MPa (125 ksi)
Elongation on 50 mm	50.0%
Hardness	243 HV
Mean grain size	ASTM 6.0
Erichsen value*	11.7 mm
Typical plastic anisotropy $\overline{R}$ value**	0.95
Shear strength	613 MPa (89 ksi)
Ratio of shear to tensile strength	0.71

* Tests carried out on a Roell and Korthaus B.P. 512 machine using 0.03 mm polyethylene sheet lubricant (BS 3855:1965).

** Mean value of a plastic anisotrophy ratio $\underline{R}$ for tests at 0°, 45° and 90° to the final rolling direction using the formula $R = \frac{1}{4}(R_{0°} + 2R_{45°} + R_{90°})$.

Annealing

Interstage annealing should be at 1040°C (1904°F) followed by a water quench or air cooling.

Machining

SOONV alloy 90 should be in the fully heat-treated condition for all machining operations. The high material hardness in this condition, 250-350 HV, requires the use of stringent machining techniques.

Welding

SOONV alloy 90 sheet is readily joined by any of the resistance welding processes. Fusion welding by conventional processes such as TIG or MIG (dip or pulsed transfer) is satisfactory for section thickness up to about 5 mm. Above this thickness microfissuring may occur in both the weld and heat-affected zone.

Electron beam, friction, inertia and flash butt welding have all been successfully applied to thickness greater than 5 mm.

The normal precautions for nickel base alloys should be observed and welding should be carried out on solution-treated material. Post weld heat-treatment is necessary to achieve optimum properties.

High Temperature Brazing

High temperature brazing in vacuum, dry hydrogen or inert atmosphere is satisfactory for SOONV alloy 90 and a number of suitable brazing alloys are available.

Available Products and Specifications

SOONV alloy 90 is designated as UNS N07090 and Werkstoff Number 2.4632. Standard product forms are sheet, strip, plate, round bar, flat bar, forging stock, wire and extruded section.

Rod, Bar, Wire and Forging Stock - BS HR2, HR501, HR502 and HR503; SAE AMS 5829; AECMA PrEN 2295, 2296, 2297, 2400, 2401, 2669 and 2670.

Plate, Sheet and Strip- BS HR202, AECMA PrEN 2298.

Pipe and Tube - BS HR402, AECMA PrEn 2299.