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Physical and Chemical Properties of Inconel 625 Materials

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Abstract: The nickel-chrome-molybdenum alloy Inconel 625 stands out based on its excellent mechanical strength and resistance against corrosion. The physical and chemical characteristics of Inconel 625 are discussed in this summary in the context of its application in many industrial applications. Its FCC lattice crystal enhances the alloy's elevated heat strength and ductility. It has a melting point of about 1,300°C (2,372°F) and excellent resistance against oxidation. Thus, this alloy stands optimally suited for application under challenging conditions like aerospace application, chemical process application, and application under marine conditions. The chemical composition of Inconel 625 makes it resistant to crevice corrosion, pitting corrosion, and the cracking of stresses due to a good amount of nickel combined with the presence of niobium and molybdenum elements. Its ability to retain strength under oxidizing and decreasing atmospheres enhances the alloy's potential. The introduction points towards the necessity of knowing the physical and chemical properties of Inconel 625 for optimizing the use of the alloy to the fullest under tough conditions and for providing safe operation under extreme situations.

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I. INTRODUCTION

➢ *Overview of Inconel 625's Chemical and Physical Properties*

Overview of Chemical and Physical Properties of Inconel 625 A nickel-based alloy, Inconel 625 (also referred to as UNS N06625 or Alloy 625), finds widespread acclaim for its excellent mechanical properties, resistance against corrosion, and stability at elevated temperatures. The alloy was first created during the 1960s as a material for use in the piping of the steam lines. Since its creation, the alloy has been applied across numerous industries and applications such as aerospace, marine, nuclear power, and chemical processes (Wikipedia). Its unique blend of features makes it a perfect material under extreme conditions of high temperature, corrosive material, and mechanical load. The physical and chemical properties of the Inconel 625 are thoroughly examined in the report based on evidence from credible sources.

INCONEL alloy 625 (UNS N06625/W.Nr. 2.4856) offers excellent strength, good workability, weldability and corrosion resistance. It also performs satisfactorily under temperature conditions ranging from cryogenic temperatures to 1800°F (982°C). The composition information is provided below (in Table 1).

The very high alloy 625 INCONEL's hardness results from the niobium and molybdenum strengthening of a nickel-chromium matrix and not requiring precipitation hardening treatment. Its composition also provides very good resistance towards exposure to severe corrosive atmospheres and conditions of elevated temperatures like oxidation and carburization.

Key features that make INCONEL alloy 625 especially ideal for application in seawater include resistance to localized attacks such as pitting and crevice corrosion, corrosion-fatigue strength that is high, high tensile strength, and good resistance against chloride-ion stress-corrosion cracking. Its utilitarian applications are wire ropes of mooring lines; propeller blades of motor patrol boat propellers; submarines' auxiliary propulsion motors; submarines' quick-disconnect mechanisms; Navy utility ships' exhaust ducts; protective sheaths over undersea telecommunication cables; transducer controllers on subs; and bellows on steam lines. Future applications could include bellows, seals, springs used in underwater control equipment, electrical cable splices, fasteners, flexure components, and oceanographic instrument parts.

The excellent and diversified corrosion resistance of INCONEL alloy 625 over broad ranges of temperatures and pressures is one of the chief reasons for the broad-based application of the alloy within the chemical process industry. Its formability makes the alloy easily shapeable into various parts for process equipment. The strength of the alloy permits the production of thinner-walled tubing or vessels of lower weight than comparable equipment materials, permitting

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better heat transmittance. Applications using the correlation of strength and corrosion resistance achievable using INCONEL alloy 625 include heat exchangers, reaction vessels, bubble caps, tubing, distillation columns, transfer pipelines, and valve components.

INCONEL alloy 625 finds application within the nuclear industry as a material for parts of the reactor core as well as the parts of the control rods of water-cooled reactors owing to its ability to provide excellent strength, excellent uniform corrosion resistance, a capacity for resistance against stress cracking, and good resistance against pitting at temperatures ranging between 500°F and 600°F (260°C to 316°C). The alloy 625 is also considered for new generations of reactors due to its allowable design strength at higher temperatures. Particularly at 1200°-1400°F (649-760°C).

Having undergone rigorous evaluation, those listed within this bulletin are the alloy's characteristics and should not be used for specification purposes. Accurate specifications are included at the end of this document standing fatigued and thermal-fatigue strength; oxidation Resistance: INCONEL alloy 625 is very weldable and brazable, representing a premium material for aerospace applications. Its applications include aircraft ducting structures, engine exhaust hardware, thrust-reverser hardware, resistance-welded honeycomb structures containing engine controls, fuel and hydraulic line tubing, spray bars, bellows, turbine shroud rings, and environmental control heat exchanger tubing. The alloy also finds application in combustion system transition liners and turbine seals.

Table 1: Chemical Composition Limiting, %

Nickel	**58.0 min**
Chromium	20.0-23.0
Iron	5.0 max
Molybdenum	8.0-10.0
Niobium (plus Tantalum)	3.15-4.15
Carbon	0.10 max
Manganese	0.50 max
Silicon	0.50 max
Phosphorus	0.015 max
Sulfur	0.015 max
Aluminum	0.40 max
Titanium	0.40 max
Cobalt[a]	1.0 max

II. BASIC THERMAL PROPERTIES AND PHYSICAL CONSTANTS

Some physical constants and thermal characteristics of INCONEL alloy 625 are included in Tables 2 and 3. Figure 1 from the National Bureau of Standards measurement illustrates the real expansion at low temperatures. The high-temperature modulus of elasticity information is listed in Table 4.

Table 2: Constants in Physical Form

Density, lb/cu in	**0.305**
gram/cc	8.44
Melting Range, °F	2350-2460
°C	1290-1350
Specific Heat[a], Btu/lb°F (J/kg°C)	
0°F (-18°C)	0.096 (402)
70°F (21°)	0.098 (410)
200°F (93°C)	0.102 (427)
400°F (204°C)	0.109 (456)
600°F (316°C)	0.115 (481)
800°F (427°C)	0.122 (511)
1000°F (538°C)	0.128 (536)
1200°F (649°C)	0.135 (565)
1400°F (760°C)	0.141 (590)
1600°F (871°C)	0.148 (620)
1800°F (982°C)	0.154 (645)
2000°F (1093°C)	0.160 (670)
Permeability at 200 Oersted (15.9 kA/m)	1.0006
Curie Temperature, °F	<-320
°C	-196

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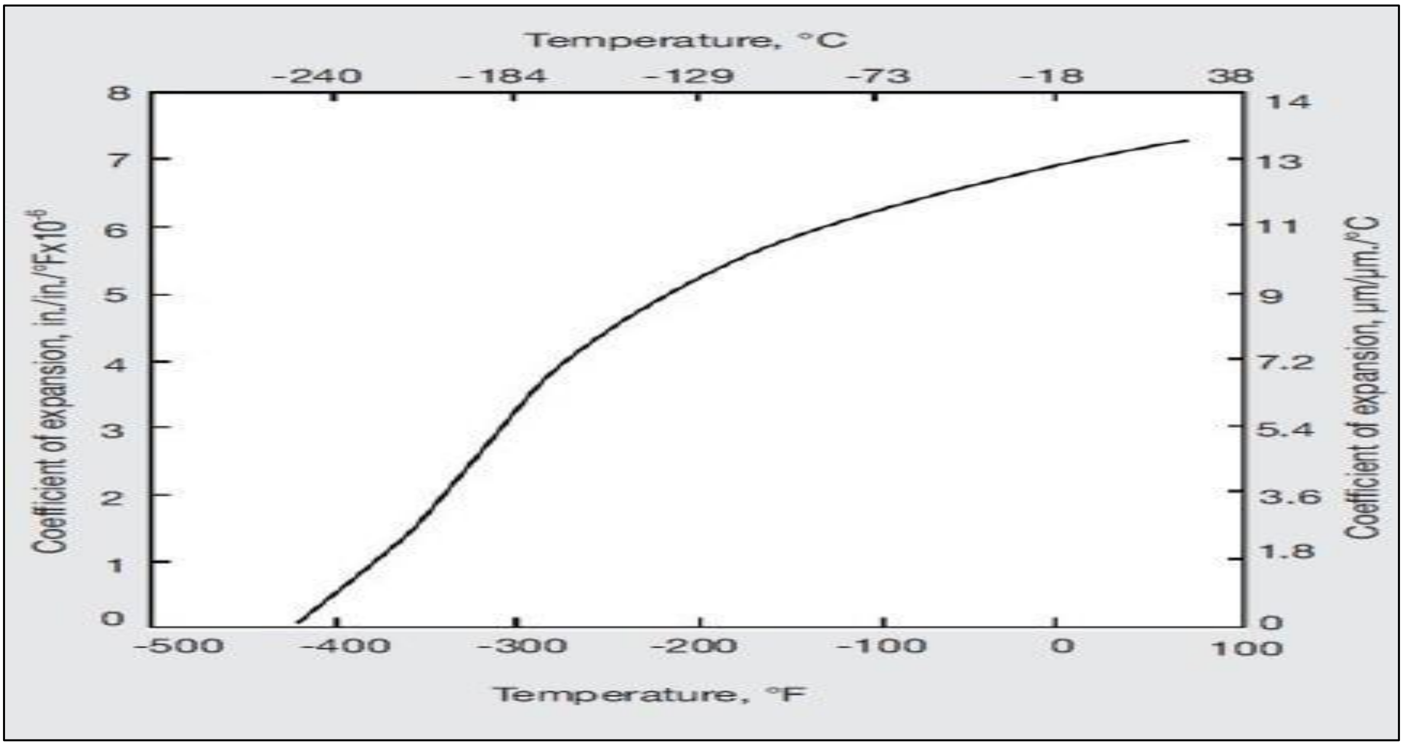

Fig 1: Heat Growth at Low Temperatures

Table 3: Electrical and Thermal Characteristics

Temp. °F	Meal Linear Expansion 10^{-6}in/in•°F	Thermal Conductivity,[c] Btu•in/ft^2-h•°F	Electrical Resistivity ohm-circ mil/ft	Temp °C	Mean Linear Expansion µm/ µm•°C	Thermal Conductivity [b,c] W/m•°C	Electrical Resistivity µΩ-cm
-250	-	50	-	-157	-	7.2	-
-200	-	52	-	-129	-	7.5	-
-100	-	58	-	-73	-	8.4	-
0	-	64	-	-18	-	9.2	-
70	-	68	776	21	-	9.8	129
100	-	70	780	38	-	10.1	130
200	7.1	75	794	93	12.8	10.8	132
400	7.3	87	806	204	13.1	12.5	134
600	7.4	98	812	316	13.3	14.1	135
800	7.6	109	818	427	13.7	15.7	136
1000	7.8	121	830	538	14.0	17.5	138
1200	8.2	132	830	649	14.8	19.0	138
1400	8.5	144	824	760	15.3	20.8	137
1600	8.8	158	818	871	15.8	22.8	136
1700	9.0	-	-	927	16.2	-	-
1800	-	175	812	982	-	25.2	135
2000	-	-	806	1093	-	-	134

From 70°F to the displayed temperature measurements made at Battelle Memorial Institute, the material annealed 2100°F/1 hr.

Table 4: Modulus at Elevated Temperatures

Temp. °F	Modulus of Elasticity, 10^3 ksi				Poisson's Ratio		Temp. °C	Modulus of Elasticity, GPa			
	Tension		Shear					Tension		Shear	
	Annealed	Solution-Treated	Annealed	Solution-Treated	Annealed	Solution-Treated		Annealed	Solution-Treated	Annealed	Solution-Treated
70	30.1	29.7	11.8	11.3	0.278	0.312	21	207.5	204.8	81.4	78.0
200	29.6	29.1	11.6	11.1	0.280	0.311	93	204.1	200.6	80.0	76.5
400	28.7	28.1	11.1	10.8	0.286	0.303	204	197.9	193.7	76.5	74.5
600	27.8	27.2	10.8	10.4	0.290	0.300	316	191.7	187.5	74.5	71.7

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800	26.9	26.2	10.4	10.0	0.295	0.302	427	185.5	180.6	71.7	68.9
1000	25.9	25.1	9.9	9.6	0.305	0.312	538	178.6	173.1	68.3	66.2
1200	24.7	24.0	9.4	9.2	0.321	0.314	649	170.3	165.5	64.8	63.4
1400	23.3	22.8	8.7	8.8	0.340	0.305	760	160.6	157.2	60.0	60.7
1600	21.4	21.5	8.0	8.3	0.336	0.289	871	147.5	148.2	55.2	57.2

[a]Derived dynamically from ¾ -in samples. hot-rolled rod.

III. MECHANICAL CHARACTERISTICS

The room temperature nominal mechanical properties of INCONEL alloy 625 are provided in Table 5.

The material should be used at temperatures not over 1200°F or below and applied in suitable hot-finished, cold-finished, or annealed conditions.

Service temperatures above 1200°F are optimum with annealed or solution-treated material. The solution-treated condition is recommended where maximum creep or failure resistance is needed. In addition, fine-grained (annealed) materials can yield benefits of improved fatigue strength, as well as improved hardness and tension and yield strengths at 1500°F.

The actual room-temperature stress-strain curve for alloy 625 was determined by employing the two-load test of MacGregor. The procedure of this experiment doesn't require the measurement of any strain; only the maximum load is applied, and the fracture load is recorded. The data on the annealed and solution-treated conditions are shown in Figure 2.

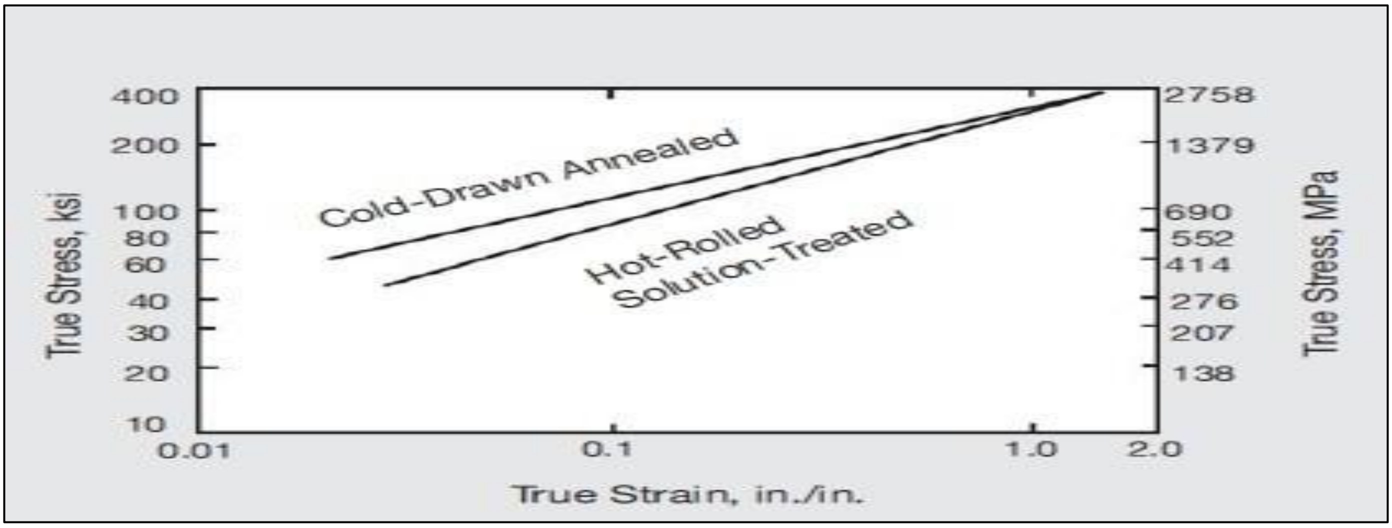

Fig 2: Stress-Strain Curve for Inconel 625.

Table 5: Nominal Room-Temperature Mechanical Properties

Form And Condition	**Tensile Strength**		**Yield Strength (0.2% Offset)**		**Elongation**	**Reduction Of Area**	**Hardness, Brinell**
	KSI	**MPa**	**KSI**	**MPa**	**%**	**%**	
ROD, BAR, PLATE							
As-Rolled	120-160	827-1103	60-110	414-758	60-30	60-40	175-240
Annealed	120-150	827-1034	60-95	414-655	60-30	60-40	145-220
Solution-Treated	105-130	724-896	42-60	290-414	65-40	90-60	116-194
SHEET and STRIP							
Annealed	120-150	827-1034	60-90	414-621	55-30	-	145-240
TUBE and PIPE, COLD-DRAWN							
Annealed	120-140	827-965	60-75	414-517	55-30	-	-
Solution-Treated	100-120	689-827	40-60	276-414	60-40	-	-

The values shown are composites for various product sizes up to 4 in. They are not suitable for specification purposes.

For properties of larger-sized products, consult Special Metals Corporation.

A. Hardness and Tensile Characteristics

Typical tensile properties of solution-treated and annealed material between room and elevated temperatures are shown in Figures 3, 4, and 5. Figure 6 shows the approximate relationship of hardness and tensile and yield strength of the strip.

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Cold working enhances the tensile properties that can be used at modest temperatures. For precise information on how this process operates, refer to the "Working Instructions" section.

Alloy 625 undergoes a small amount of hardening when exposed to intermediate temperatures. To demonstrate the effect, rod pieces were annealed and tested at 1200°, 1400°, and 1600°F for 2000 hours. The room temperature and exposure temperature effects of this exposure are summarized in Table 6. The tests on dimensional stability showed that the pieces tested within the temperature range of 1200° to 1400°F for two thousand hours showed a contraction of nearly 0.048%.

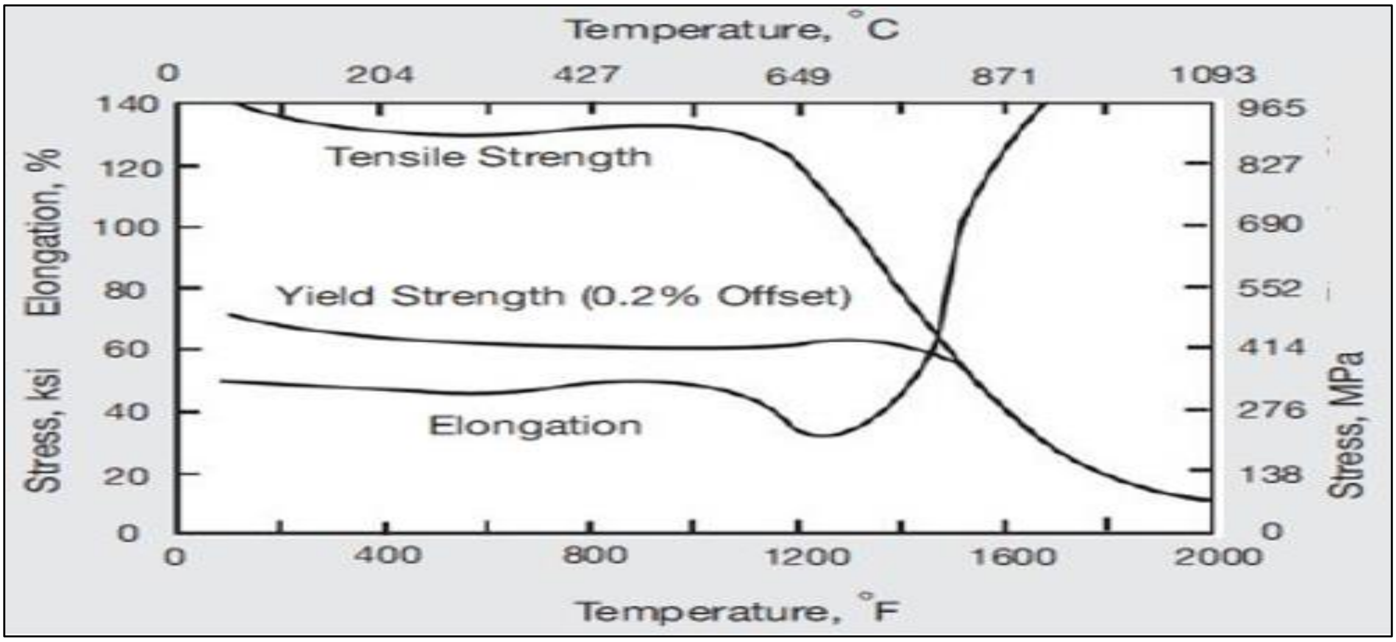

Fig 3: High-Temperature Tensile Properties of Annealed Bar.

Table 6: Effect of Intermediate-Temperature Exposure (2000 hrs) on Properties of Hot-Rolled Annealed Bar

Exposure Temperature, °F (°C)	Properties at Room Temperature					Properties at Exposure Temperature				
	Tensile Strength		Yield Strength (0.2% offset)		Elongation, %	Tensile Strength		Yield Strength (0.2% offset)		Elongation, %
	ksi	MPa	KSI	MPa		ksi	MPa	ksi	MPa	
No Exposure	140.0	965.3	69.5	479.2	54	-	-	-	-	-
1200 (649)	176.0	1213.5	126.5	872.2	30	146.5	1010.1	106.5	734.3	54
1400 (760)	163.0	1123.8	107.0	737.7	26	84.8	584.7	79.0	544.7	62
1600 (871)	144.0	992.8	76.7	528.8	34	41.2	284.1	40.0	275.8	80

[a]Values shown are composites for various product sizes up to 4 in. They are not suitable for specification purposes. For properties of larger-sized products, consult Special Metals Corporation.

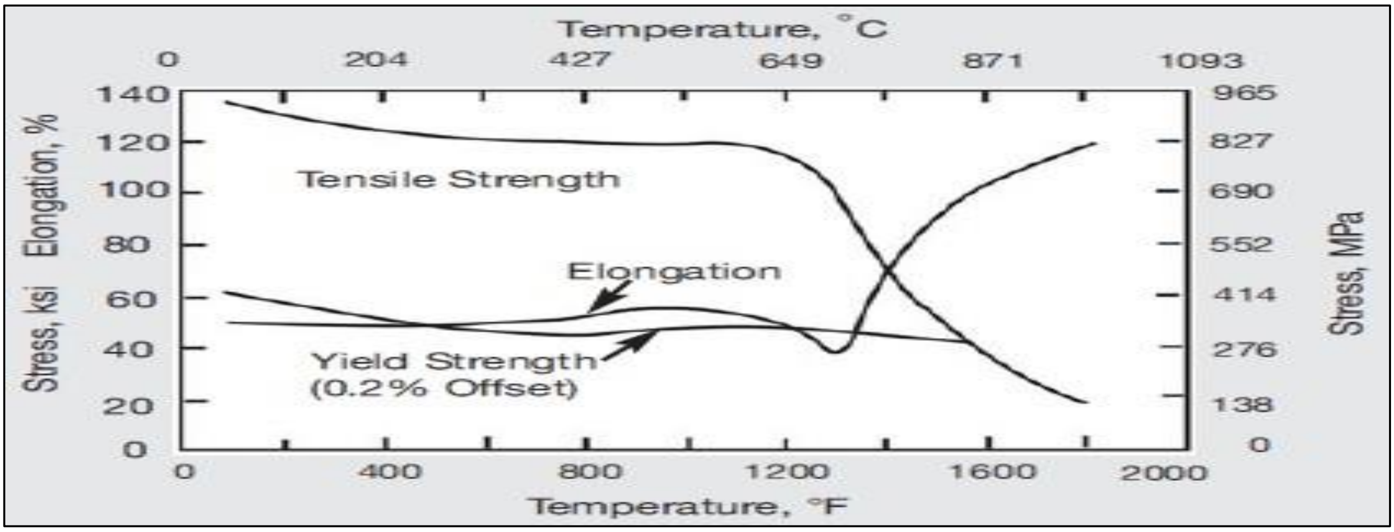

Fig 4: High-Temperature Tensile Properties of Cold-Rolled Annealed Sheet

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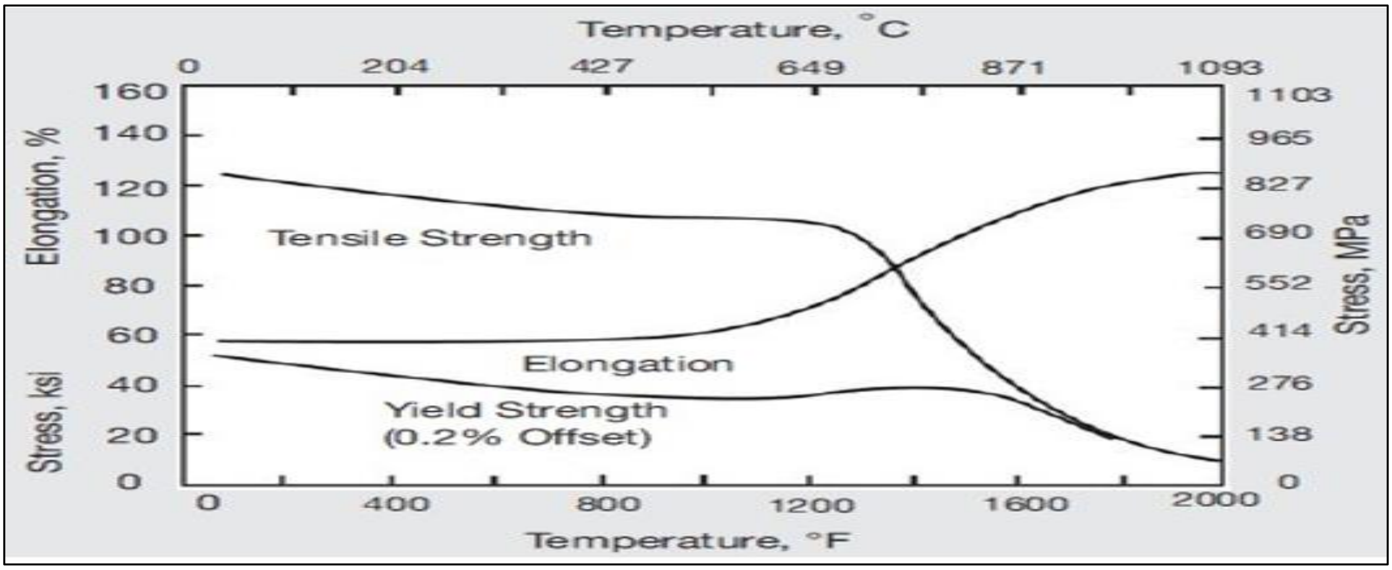

Fig 5: High-Temperature Tensile Properties of Hot-Rolled Solution-Treated Rod.

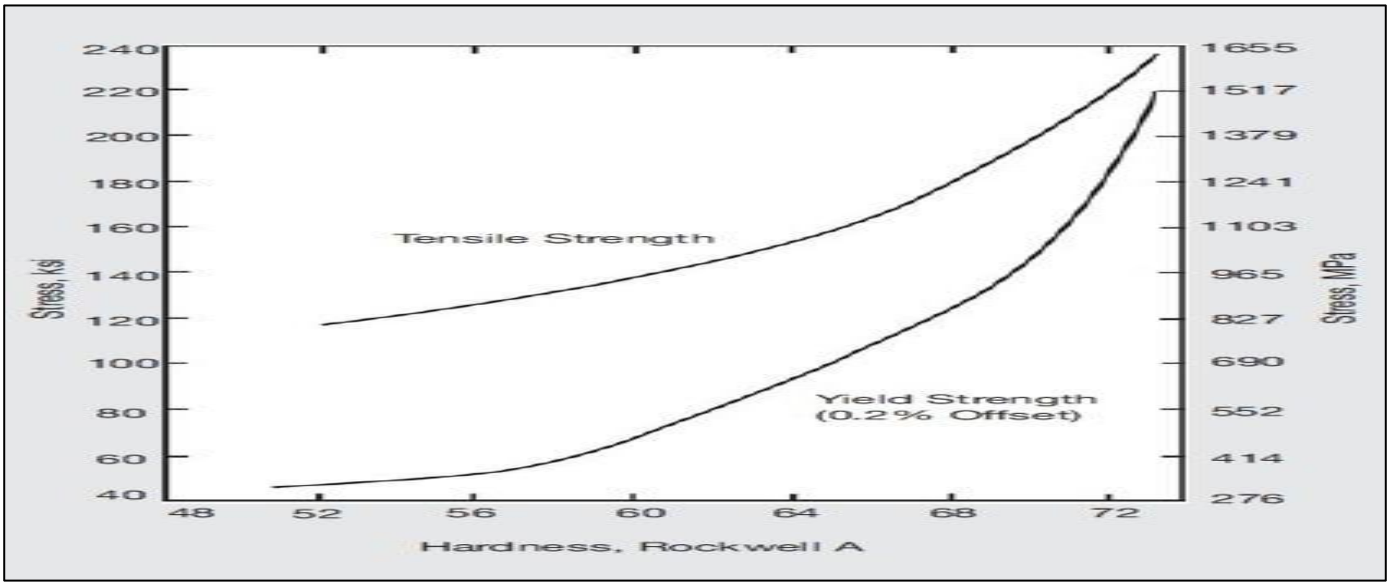

Fig 6: Approximate Relationships between Hardness and Tensile Properties of the Strip

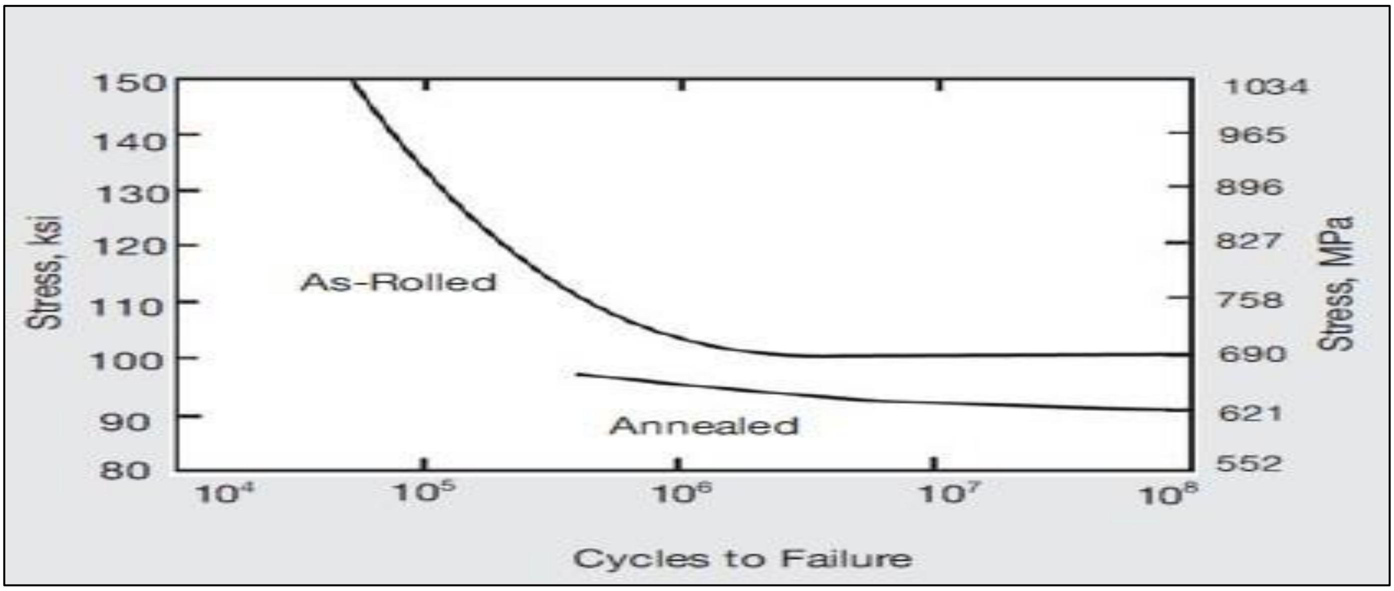

Fig 7: Fatigue Strength of Hot-Rolled Round (5/8-Inch Diameter) at Room Temperature

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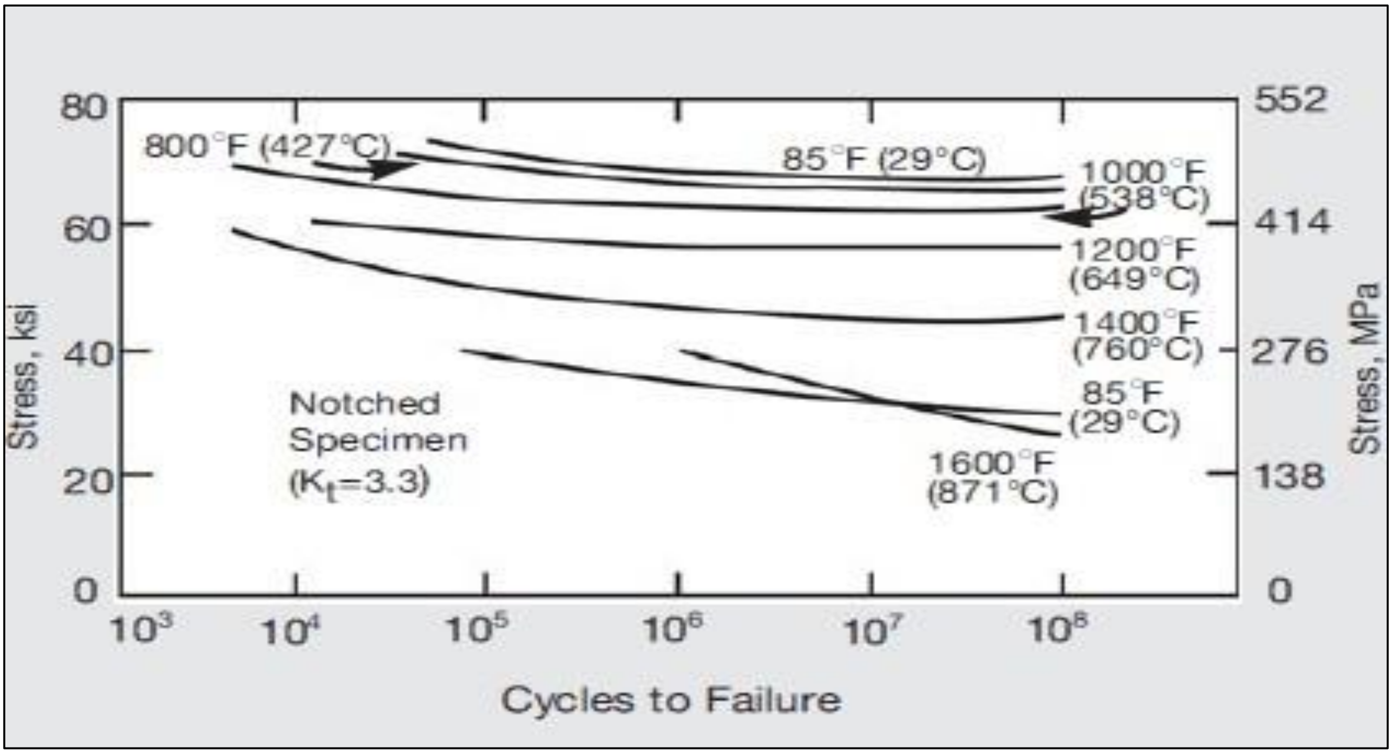

Fig 8: Rotating-Beam Fatigue Strength of 0.625-inch-Diameter Hot-Rolled Solution-Treated Bar at High Temperatures. Grain Size Average: 0.004 in

B. Strength of Fatigue

Figure 7 indicates the room-temperature fatigue strength of hot-rolled round bars under the as-rolled and annealed conditions. Figures 8 and 9 compare elevated-temperature strengths of solution-treated and annealed bars.

The room temperature endurance limit (at 10^8 cycles) for the brittle annealed sheets under fully reversed flexure was established as 90,000 psi for smooth specimens and 35,000 psi for the notched specimens with a Kt value of +3.3.

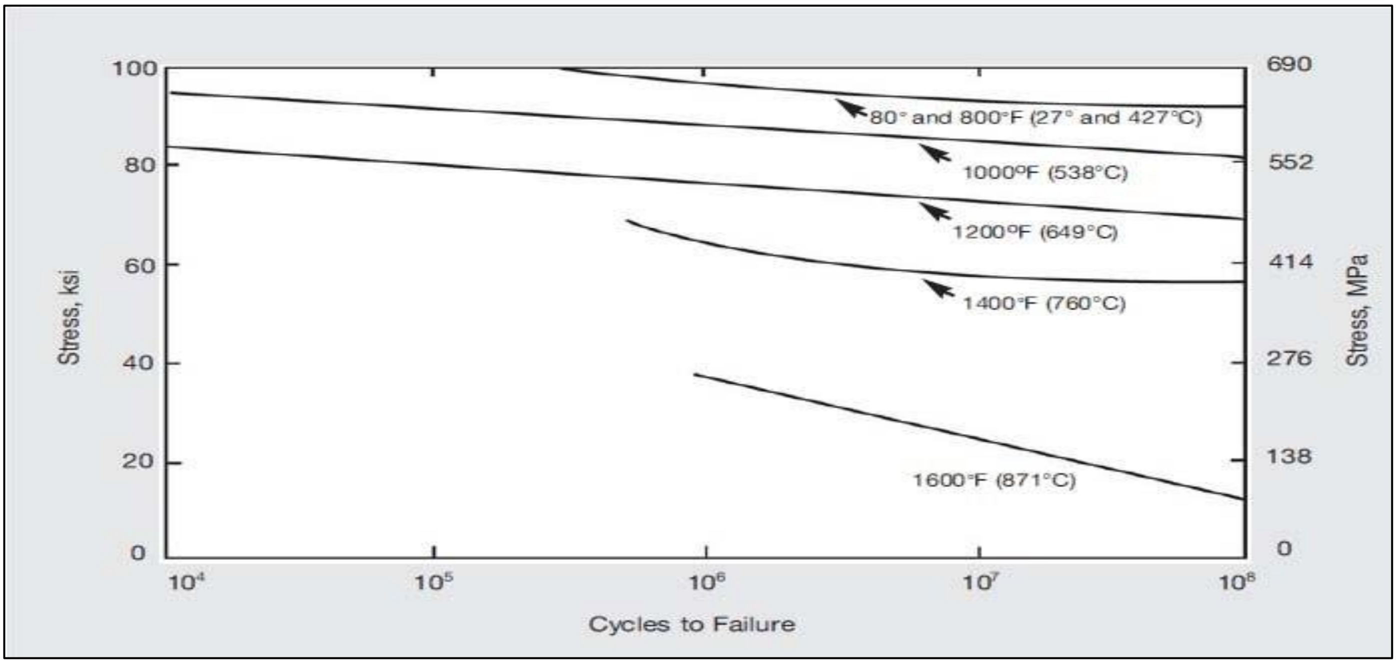

Fig 9: Rotating-Beam Fatigue Strength at High Hot-Rolled, Annealed Bar Temperatures with a Diameter of 0.625 inches. Grain Size Average: 0.0006 in.; Hardness at Room Temperature: 24.5 Rc.

C. Ductility and Toughness

Alloy 625 INCONEL: The alloy's toughness and ductility are preserved below -320°F. Tensile and impact data as low as -320°F are presented in Table 7 and Figure 10.

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Table 7: Low-Temperature Impact Strength of Hot-Rolled, As-Rolled Plate (1/2-in. thickness)

Test Temperature,		**Orientation**	**Impact Strength,**	
°F	**°C**		**ft•lb**	**J**
85	29	Longitudinal	48, 49, 50	65, 66, 68
		Transverse	46, 49, 51.5	62, 66, 70
-110	-79	Longitudinal	39, 44, 49	53, 57, 60
		Transverse	39, 42, 44	53, 57, 60
-320	-196	Longitudinal	35, 35, 35.5	47, 47, 48
		Transverse	31, 32, 36	42, 43, 49

[a]Charpy keyhole specimens in triplicate.

D. Reep and Rupture Strength

The overall creep and rupture strength of the solution-annealed material is illustrated in Figures 11 and 12.

To compare this, the creep and rupture of the annealed material are indicated in Figures 13 and 14. If used for other applications, the creep-rupture behavior of annealed materials will be adequate for other applications. However, they will be inferior to those of the solution-treated materials.

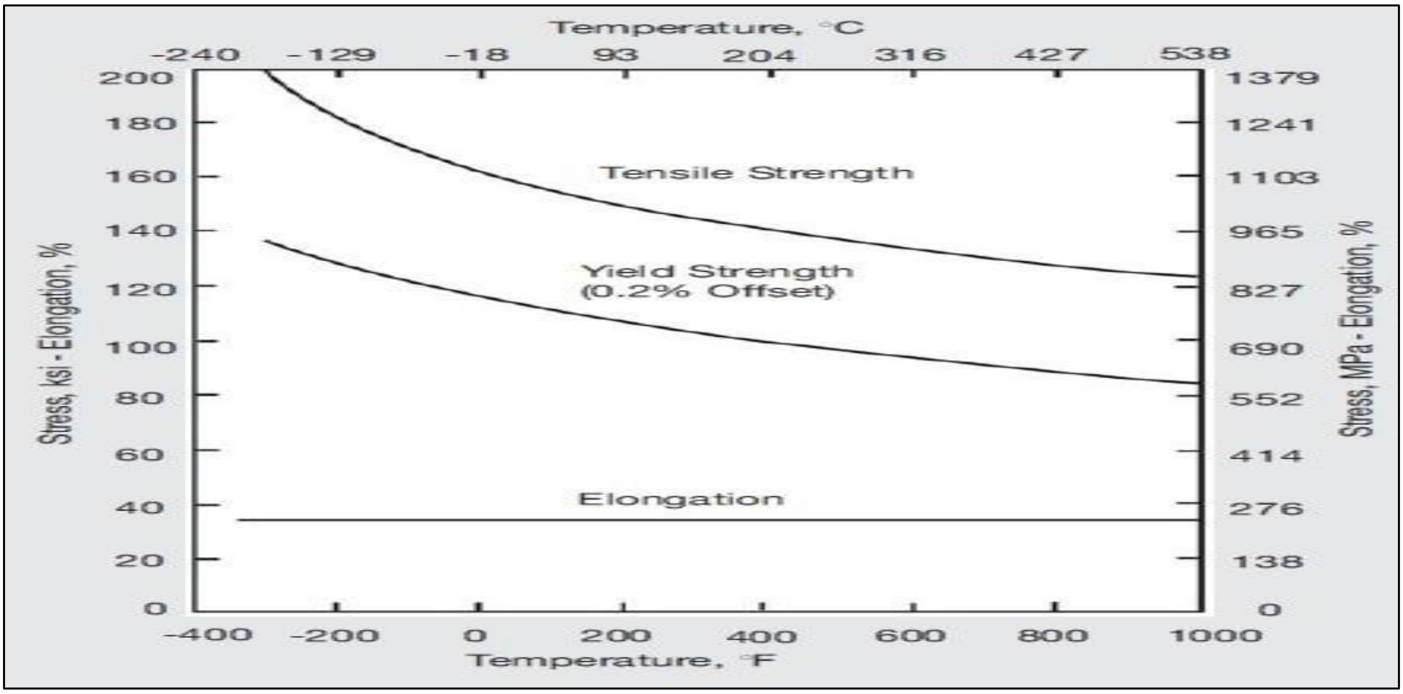

Fig 10: Tensile Properties of Cold-Rolled (20% Reduction), as-Rolled Sheet (0.024 Gages) from Low to Elevated Temperatures

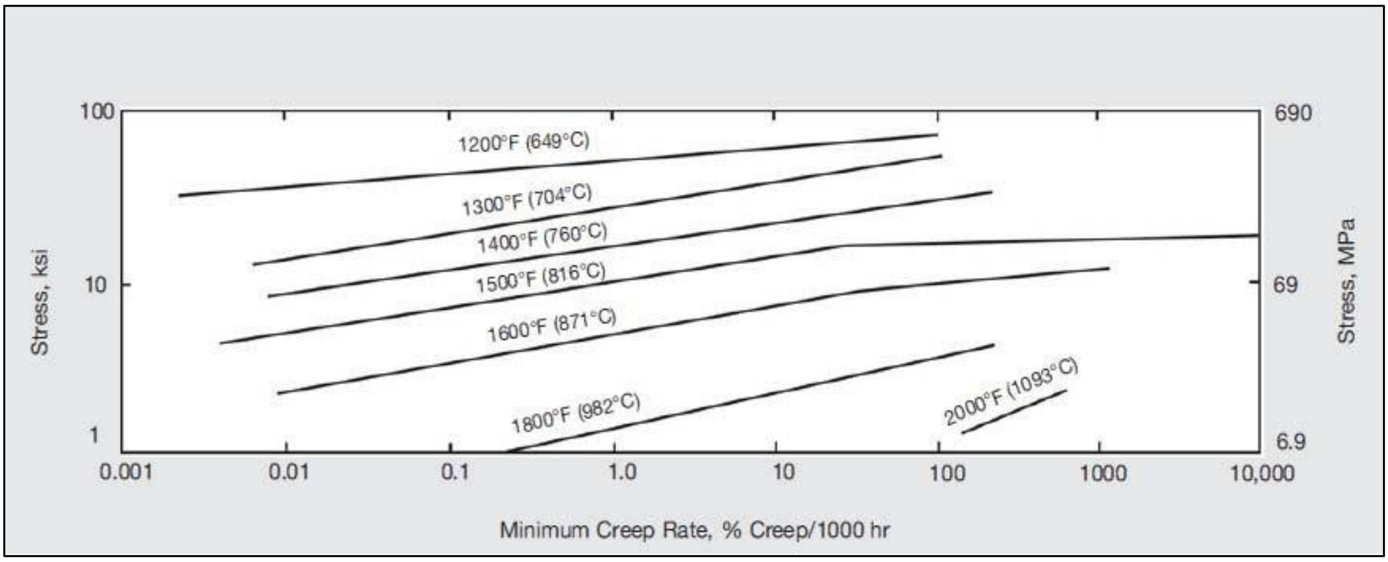

Fig 11: Creep Strength of Solution-Treated Material.

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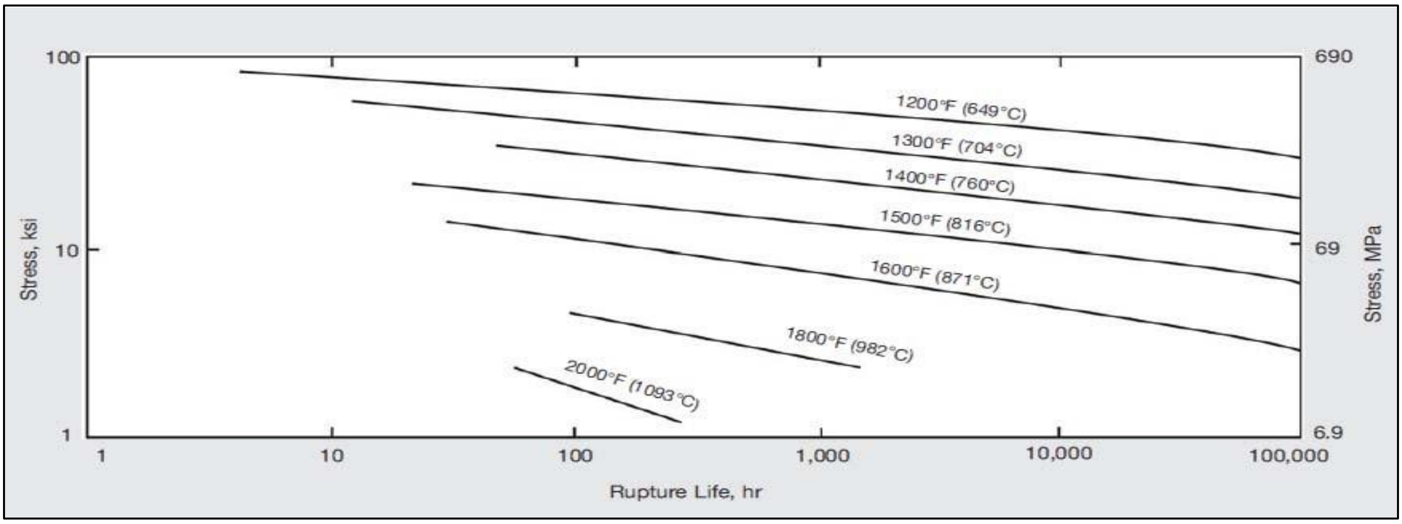

Fig 12: Rupture Life of Solution-Treated Material

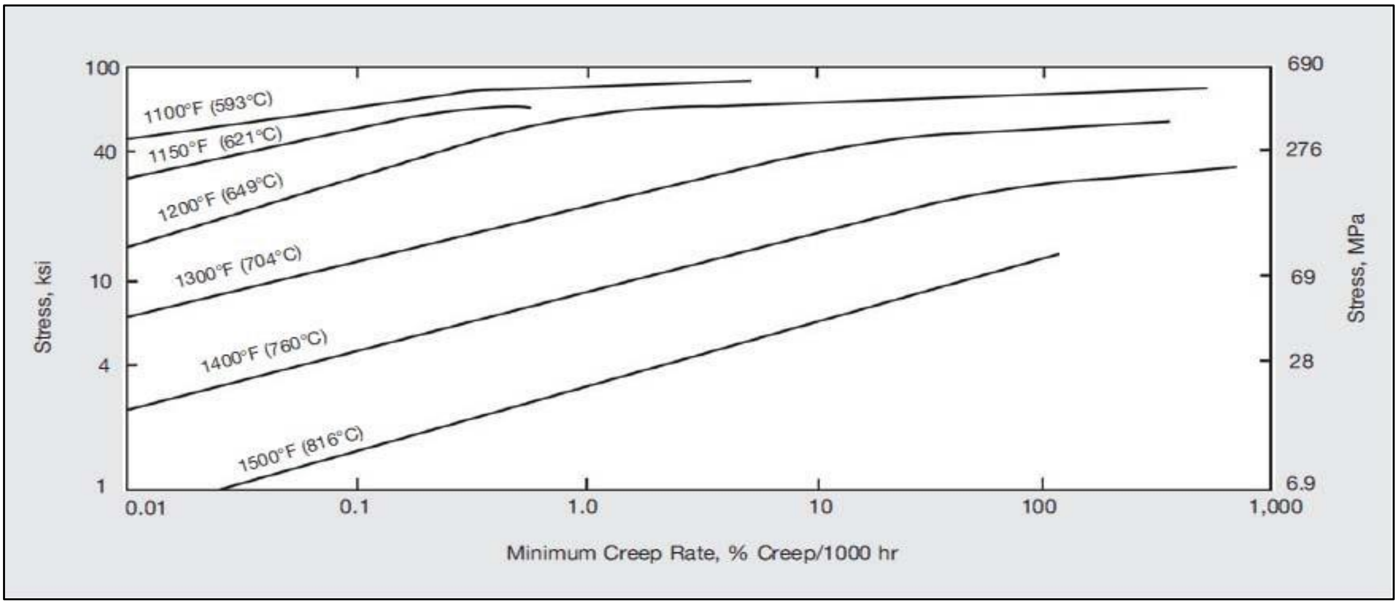

Fig 13: Creep Strength of Annealed Material

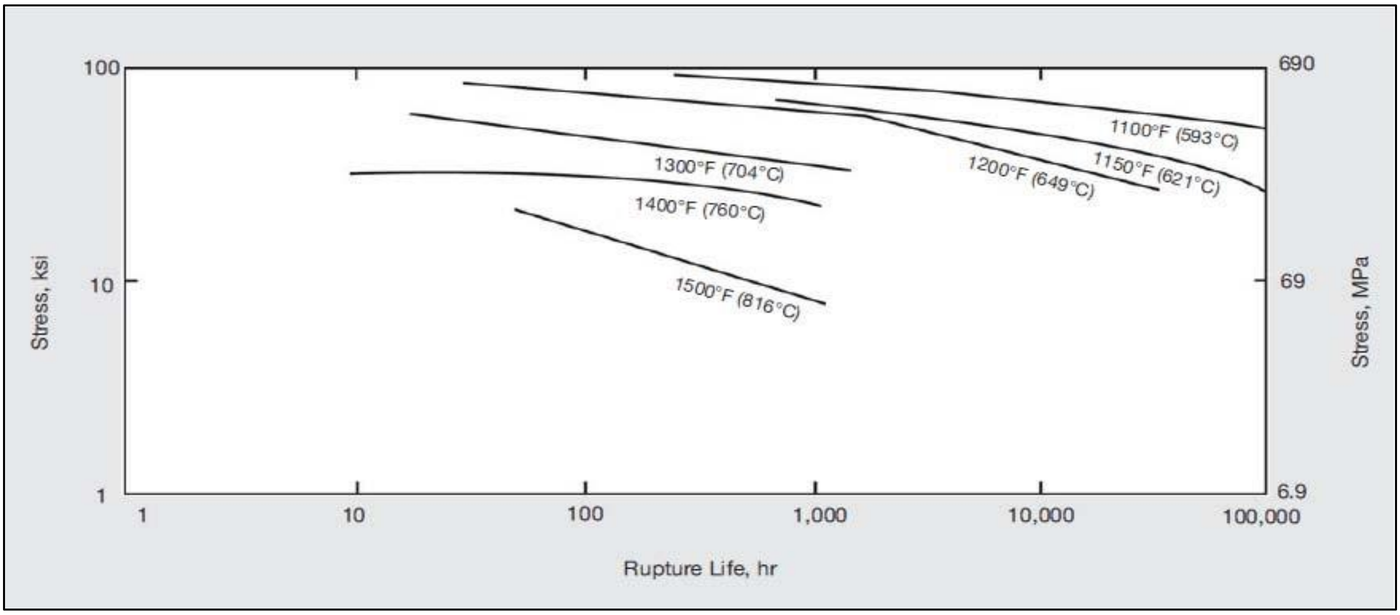

Fig 14: Rupture Life of Annealed Material

E. ASME Boiler and Pressure Vessel Code

INCONEL alloy 625 may be used as a satisfactory construction material as per the American Society of Mechanical Engineers' Boiler and Pressure Vessel Code. For Grade 1 material under Grade 1 construction of Section VIII, Division 1, the maximum allowable design stresses of 1200°F may be permitted. For Section III's Class 2 and 3 constructions, the identical grade shall be used for temperatures up to 800°F. Information regarding allowable limits of stresses of Grade 2 material for Section VIII, Division 1 service having the upper-temperature limit of up to 1600°F is provided under ASME Section II, Part D Table 1B. In addition, provisions regarding allowable stresses of Grade I materials under the construction of Section I—allowing the level of operation temperatures up to 150 °F—are provided under ASME Code Case 1935.

F. Microstructure

INCONEL alloy 625 is a face-centered-cubic alloy strengthened by a solid-solution matrix. Such an alloy can contain carbides of the MC and M6C types as well as niobium, nickel, molybdenum, and carbon enrichments. The chromium-rich carbide M23C6 may also be held in solution-treated material following lower-temperature exposure.

The warpage experienced by the alloy on exposure at temperatures close to 1200°F (see the Mechanical Properties subsection) results from slow precipitation of a nickel-niobium-rich phase named gamma prime. As the time at elevated intermediate temperatures increases, progressively, this phase transforms into the orthorhombic Ni3Nb.

Extensive investigations of the stability of alloy 625 after long-time exposure within the temperature interval of 1000°F to 1800°F have demonstrated the absence of embrittling phases like sigma.

IV. CORROSION RESISTANCE

A. Aqueous Corrosion

The heavy alloy content in INCONEL alloy 625 renders it strong enough to sustain a wide range of harsh corrosive conditions. Little corrosion occurs on the material within mild corrosive conditions such as the atmosphere, fresh seawater, alkaline solution, and neutral salts. In more severe corrosive conditions, chromium and nickel protect against oxidizers; at the same time, they offer protection against non-oxidizing conditions by their very high nickel and molybdenum content. In addition, the high content of molybdenum ensures the alloy's resistance against crevice and pitting types of corrosion. Niobium plays a crucial role as it prevents the alloy from sensitization while undergoing weldment, so it resists any intergranular cracking that might happen later. Its heavy nickel content also reduces the alloy's vulnerability to chloride-ion stress-corrosion cracking.

The innovative blend of characteristics of the INCONEL alloy 625 makes this suitable for use within a broad assortment of corrosive conditions. It has been approved as a suitable building material for chemical waste tanks for holding hydrochloric and nitric acids—those materials that present varying corrosiveness concerns. Materials resistant to one acid generally are not resistant to the other.

For more information, go to our publication, 'High-Performance Alloys for Resistance to Aqueous Corrosion,' on our website.

B. High-Temperature Oxidation

INCONEL alloy 625 offers satisfactory resistance against scaling and oxidation exposure at elevated temperatures. The way this material behaves under a very severe test, as opposed to how other materials behave under the test, is shown in Figure 15. The intermittent weight loss during this test measures the ability of the alloy to sustain a protective scale under very severe cyclic conditions. Scaling resistance becomes more crucial to its service application at 1800°F.

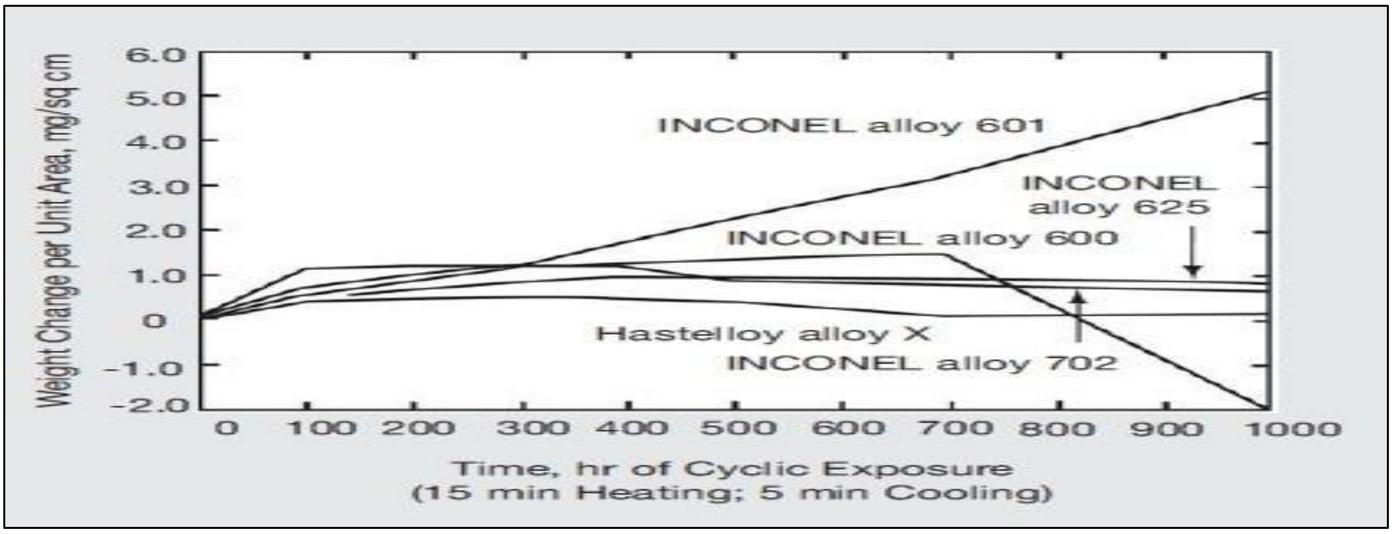

Fig 15: Scaling Resistance at 1800°F (Hastelloy® is a Trademark of Haynes International)

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C. Working Instructions

- *Heating*

The hot- or cold-formed parts are usually annealed between 1700°F and 1900°F, and the time taken is proportional to thickness. Softening for other uses of cold work may be enhanced by higher temperatures. INCONEL alloy 625 solution-anneals between 2000°F and 2200°F. It should be noted that such provided temperatures are applicable for batch treatment specifically and might not be applicable for cases involving continuous annealing by default, meaning short times of exposure within a furnace's higher-heat zones having temperatures elevated. The cooling rate after heating does not significantly affect INCONEL alloy 625.

Stress relief conditions best suited for the alloy may be determined by using referential values in Tables 8 and 9.

Heating the cold-worked materials between 1100°F and 1400°F successfully relieves the residual stresses; almost complete relief occurs when the materials are heated close to 1600°F.

Figure 16 shows how different degrees of cold reduction affect the levels of sheets' hardness after annealing.

Table 8: Impact of One-Hour Annealing on Hot-Rolled Rod's Room-Temperature Properties

Annealing Temperature, °F	**Tensile Strength, ksi**	**Yield Strength (0.2% Offset), ksi**	**Elonga- on, %**	**Reduction Of Area, %**	**Hardness, Rb**
As-Rolled	147.5	92.0	46.0	55.3	98
1400	145.5	90.8	43.0	49.5	101
1500	143.5	85.0	42.0	45.7	101
1600	145.5	87.2	39.0	41.5	101
1700	147.0	86.0	40.0	48.0	103
1800	143.5	83.6	44.0	48.0	101
1850	142.5	78.6	46.0	53.0	99
1900	142.5	66.3	49.0	51.5	95
2000	124.0	52.5	64.0	62.5	93
2100	116.0	50.0	62.0	61.0	89
2200	116.5	48.0	72.0	61.3	88
Annealing Temperature, °C	**Tensile Strength, MPa**	**Yield Strength (0.2% Offset), MPa**	**Elonga- on, %**	**Reduction Of Area, %**	**Hardness, Rb**
As-Rolled	1017.0	634.3	46.0	55.3	98
760	1003.2	626.0	43.0	49.5	101
816	989.4	586.1	42.0	45.7	101
871	1003.2	601.2	39.0	41.5	101
927	1013.5	593.0	40.0	48.0	103
982	989.4	576.4	44.0	48.0	101
1010	982.5	542.0	46.0	53.0	99
1038	982.5	457.1	49.0	51.5	95
1093	855.0	362.0	64.0	62.5	93
1149	799.8	344.7	62.0	61.0	89
1204	803.2	331.0	72.0	61.3	88

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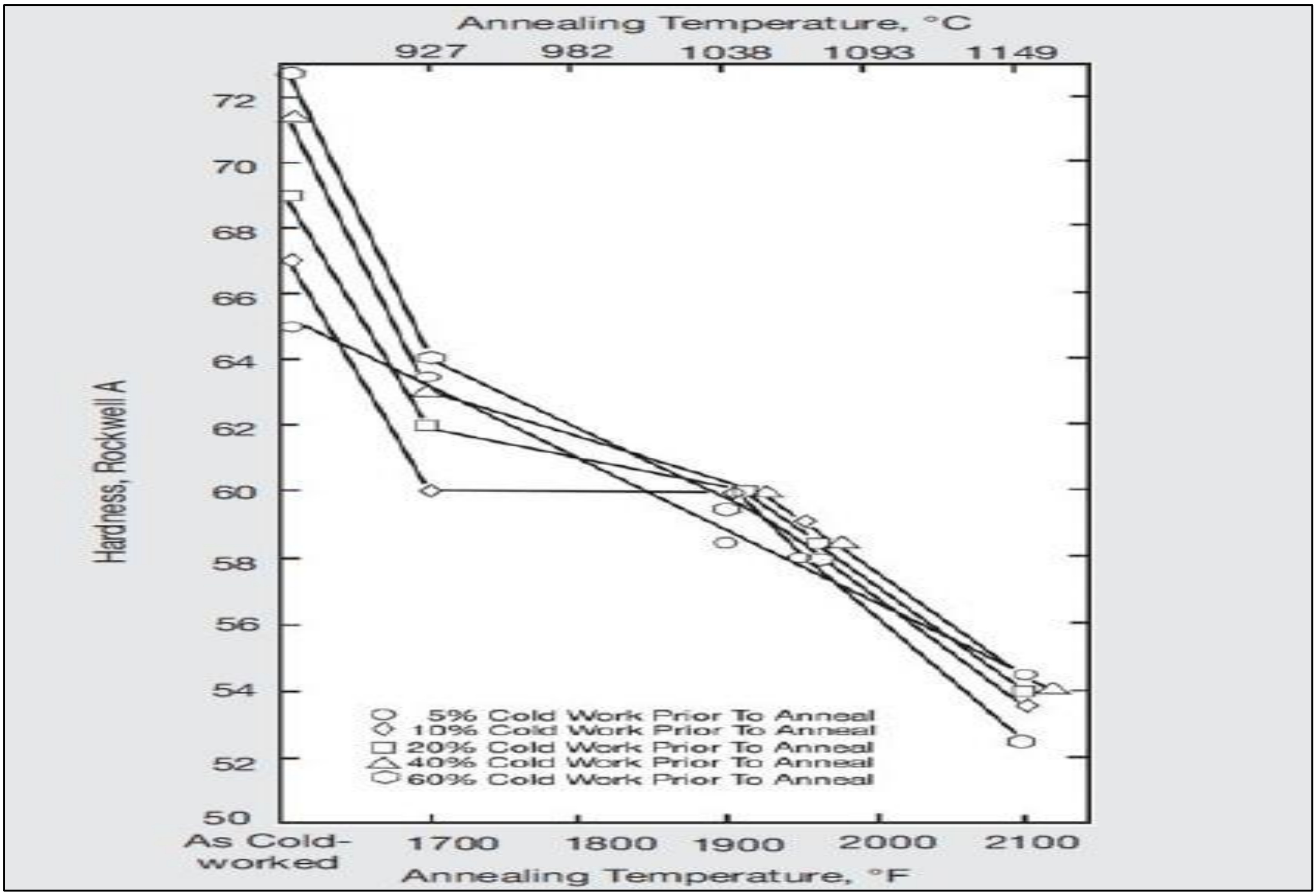

Fig 16: Impact of Annealing Temperature (30 Min at Temperature) on Sheet Hardness

Table 9: Impact of One-Hour Annealing on Cold-Drawn Rod's Room-Temperature Properties

Annealing Temperature,		**Tensile Strength,**		**Yield Strength (0.2% Offset),**		**Elongation %**	**Reduction Of Area, %**	**Hardness, Rb**	**Impact Strength (Charpy V)**		**Grain Size,**	
°F	°C	ksi	MPa	ksi	MPa				ft•lb	J	in.	mm
As-Drawn	As-Drawn	163.0	1123.8	145.5	1003.2	21.0	50.5	106	64.5	87.5	0.003	.076
1100	593	160.5	1106.6	134.3	926.0	28.0	48.3	106	75.0	101.7	0.0035	.089
1200	649	159.5	1099.7	133.5	920.5	28.5	47.2	106	71.5	97.0	0.0045	.114
1300	704	164.0	1130.7	135.0	930.8	26.0	38.8	106	57.0	77.3	0.005	.127
1400	760	162.5	1120.4	135.5	934.2	27.0	39.0	106	53.0	71.9	0.005	.127
1500	816	152.0	1048.0	120.0	827.4	29.0	41.5	105	55.0	74.6	0.0035	.089
1600	871	146.5	1010.1	102.5	706.7	35.0	45.2	103	62.0	84.1	70% 0.005	.127
											30% 0.009	.229
1700	927	133.5	920.5	62.3	429.5	48.5	44.0	97	82.5	111.9	0.0008	.203
1800	982	127.5	879.1	62.3	429.5	52.0	55.3	95	84.5	114.6	0.0009	.229
1900	1038	130.5	899.8	60.8	419.2	53.0	55.7	95	91.0	123.4	0.0008	.203
2000	1093	126.5	872.2	56.5	389.6	57.0	61.0	93	115.5	156.6	0.0019	.048
2100	1149	118.0	813.6	48.3	333.0	63.0	60.4	89	138.0	187.1	0.0032	.081
2200	1204	113.0	779.1	44.6	307.5	62.3	58.4	86	141.0	191.2	0.006	.152

➢ *Pickling*

Heating INCONEL alloy 625, like most nickel-chromium and nickel-chromium-iron alloys, forms a good adhering oxide scale or coating unless the alloy has been bright annealed under very dry hydrogen or a vacuum. Pre-treating by submerging the alloy in a molten salt bath before pickling is generally recommended to remove the heat-bonded oxide. Information regarding suitable salt baths and pickling compounds may be obtained from the Fabricating booklet.

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➢ *Hot and Cold Forming*

Since INCONEL alloy 625 was created to be tough at elevated temperatures, it resists hot working deformation. Hot-forming procedures may shape it easily if solid equipment is used properly. When INCONEL alloy 625 is being hot formed, the metal needs to be heated inside a furnace where heat is maintained at a level not higher than 2150°F. The metal is heated as close as possible to 2150°F as conditions permit. Heavy reduction occurs between 2150°F and 1850°F and light reduction up to 1700°F. Reductions should be done evenly to avoid duplex grain structure. The last minimum reduction should be between 15% and 20% for open-die work.

INCONEL alloy 625 may be cold-formed by standard methods. The required shearing force for cold forming the alloy within the annealed condition is illustrated in Figure 17.

Further information regarding its resistance to deformation is provided by the true stress-true strain curves (referenced within the "Mechanical Properties" section of this bulletin) as well as by the examination of the influence of cold work on the hardness (such as illustrated in Figure 18).

Medium-temperature uses are supplemented by the improved tensile characteristics obtained using cold work procedures. Tensile strengths over 300,000 psi accompanied by adequate ductility have resulted from wire diameters of .010 to .020 inches after a cold work reduction of about 75%-90% (See Table 10). The results of cold work on plate material are indicated in Table 11.

Consult the publication 'Fabricating' for full information about hot and cold forming procedures suitable for application on INCONEL alloy 625.

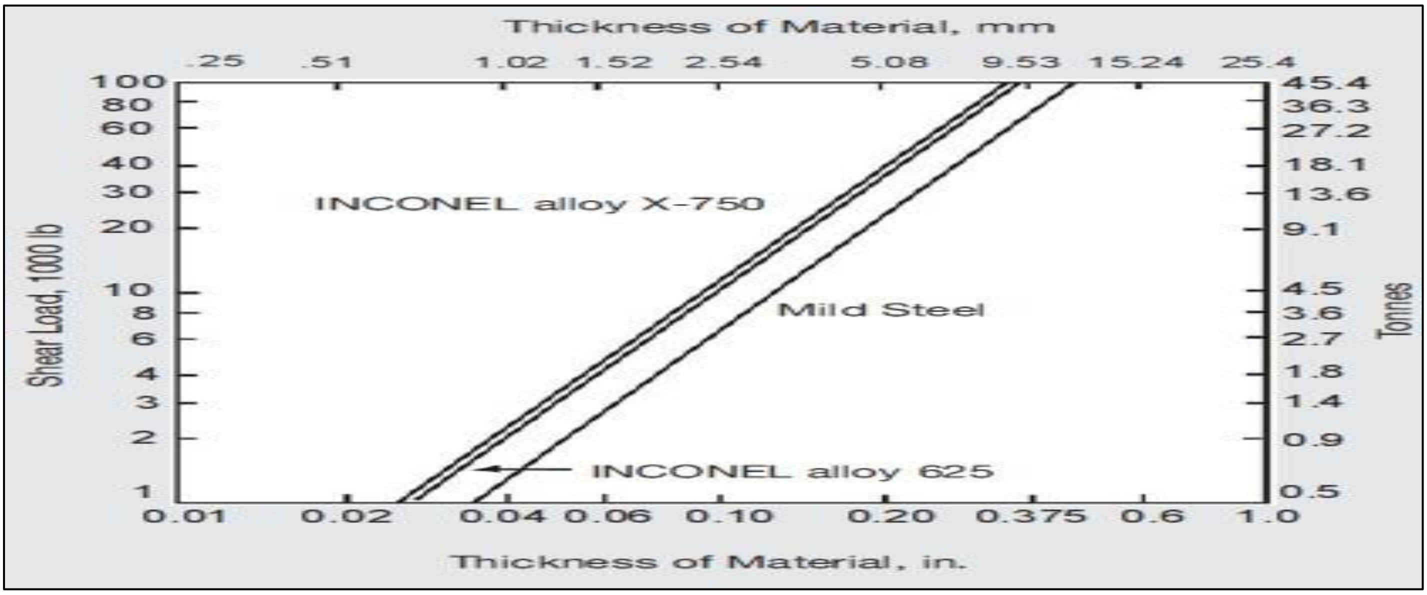

Fig 17: The Loads Needed to Shear Annealed Material (21/64 in./ft Knife Rake, Hydraulic Shear)

Table 10: Tensile Characteristics of As-Drawn Wire at Room Temperature

Wire Diameter,		Cold Reduc-tion, %	Tensile Strength		Yield Strength (0.2% offset)[b],		Elonga- tion In 10 Inches, %
In.	Mm		ksi	MPa	ksi	MPa	
0.0397[c]	1.008[c]	0	138	952	61.5	424	52.3
0.036	0.914	19	174.5	1203	153.3	1057	17.5
0.0318[d]	0.808[d]	37	220	1517	205	1413	2.0
0.0285[d]	0.724[d]	49	246	1696	218	1503	2.0
0.0253[d]	0.643[d]	60	269	1855	253	1744	2.4
0.0226[d]	0.574[d]	68	283	1951	242	1669	2.2
0.020[d]	0.508[d]	75	293	2020	251	1731	2.0
0.0179	0.455	80	295.3	2036	220	1517	3.8
0.0159	0.404	84	303	2089	250	1727	3.4
0.0142	0.361	87	306	2110	252.8	1743	3.0
0.0126	0.320	90	316	2181	269	1855	2.6
0.0111	0.282	92	316	2179	264	1820	2.3
0.0099	0.251	94	322.3	2222	274.5	1893	3.0

[a]average of 2 tests unless otherwise shown.
[b]Crosshead speed, 0.1 in./min.
[c]strand-annealed at 2150°F, 29 ft/min, in a 10-ft furnace with a 6-7 ft hot zone
[d]One test.

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Table 11: Impact of Cold Work on Mechanical Characteristics of Strips Cut From Hot-Rolled Plate (0.372-in.), Solution-Treated at 2150°F for 1 hour, and Cold Worked

Cold Reduction, %	Tensile Strength		Yield Strength (0.2% offset)[b]		Elongation %	Reduction Of Area, %	Hardness	
	ksi	MPa	ksi	MPa			Rockwell C	Vickers
0	115.5	796.3	49.5	341.3	67.0	60.4	88 Rb	179
5	121.0	834.3	77.5	534.3	58.0	58.1	94 Rb	209
10	130.0	896.3	102.5	706.7	47.5	54.6	25	257
15	137.0	944.6	112.5	775.7	39.0	51.9	32	309
20	143.0	986.0	125.0	861.8	31.5	50.0	34	326
30	165.0	1137.6	152.0	1048.0	17.0	49.3	36	344
40	179.5	1237.6	167.0	1151.4	12.5	41.9	39	372
50	189.5	1306.6	177.0	1220.4	8.5	38.0	40	382
60	205.0	1413.4	180.5	1244.5	6.5	32.7	44	427
70	219.0	1510.0	201.0	1385.8	5.0	25.4	45	440

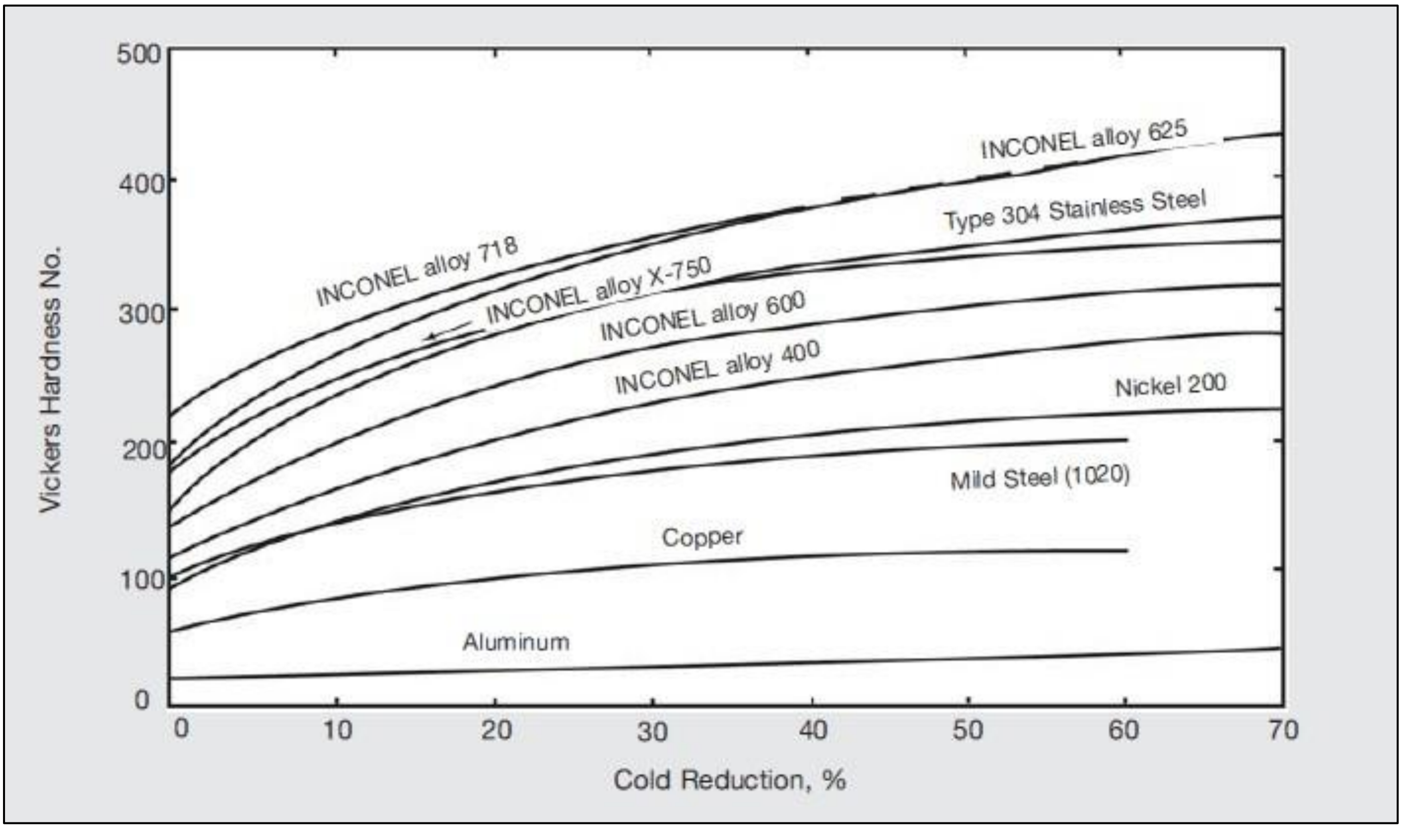

Fig 18: Cold Work's Impact on Toughness

V. AVAILABLE PRODUCTS AND SPECIFICATIONS

INCONEL alloy carries the designation UNS N06625, Werkstoff Number 2.4856, and ISO NW6625, meeting NACE MR-01-75. The alloy is manufactured in several mill form standards varying from rods, bars, wire, wire rods, plates, sheets, strips, shapes, and tubular products to forging stock. Available products and purchasing procedure details are available in the offices on the reverse side.

Rod, Bar, Wire and Forging Stock - ASTM B 446/ASME SB 446 (Rod & Bar), ASTM B 564/ASME SB 564 (Forgings), SAE/AMS 5666 (Bar, Forgings, & Rings), SAE/AMS 5837 (Wire), ISO 9723 (Rod & Bar), ISO 9724(Wire), ISO 9725 (Forgings), VdTÜV 499 (Rod & Bar), BS 3076NA21 (Rod & Bar), EN 10095 (Rod, Bar, & Sections), DIN 17752 (Rod & Bar), ASME Code Case 1935 (Rod, Bar, & Forgings), DIN 17754 (forgings), DIN 17753 (Wire).

- **Plate, Sheet and Strip -** ASTM B 443/ASTM SB 443 (Plate, Sheet & Strip), SAE/AMS 5599 & 5869 & MAM 5599 (Plate, Sheet & Strip), ISO 6208 (Plate, Sheet & Strip), VdTÜV 499 (Plate, Sheet & Strip), BS 3072NA21 (Plate & Sheet), EN 10095 (Plate, Sheet & Strip), DIN 17750 (Plate, Sheet & Strip), ASME Code Case 1935.
- **Pipe & Tube -** ASTM B 444/B 829 & ASME SB 444/SB 829 (Seamless Pipe & Tube), ASTM B704/B 751 & ASME SB 704/SB 751 (Welded Tube), ASTM B705/B 775 & ASME SB 705/SB 775 (Welded Pipe), ISO 6207 (Tube), SAE/AMS 5581 (Seamless & Welded Tube),

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VdTÜV 499 (Tube), BS 3074NA21 (Seamless Pipe & Tube), DIN 17751 (Tube), ASME Code Case 1935.
- **Other Product Forms -** ASTM B 366/ASME SB 366 (Fittings), ISO 4955A (Heat Resisting Steels & Alloys), DIN 17744 (Chemical composition of all product forms).

VI. CONCLUSION

Its superior physical and chemical characteristics make Inconel 625 a unique alloy. It contributes excellent strength, corrosion resistance, and resistance to severe conditions. Its high strength and corrosion resistance make the alloy a good material for aerospace, marine, and chemical processing. The adaptability of the alloy makes the material enduring as innovations never stop helping the alloy keep up with the demands of addressing engineering issues of the time. Efficiency, reliability, and sustainability are the industry's priorities, making Makingnel 625 a cornerstone of demanding applications.

A. Physical Properties of Inconel 625

➢ *Mechanical Strength*

Inconel 625 possesses superior mechanical strength, especially at elevated temperatures. At room temperature, it has a yield strength of 69.5 ksi (479.2 MPa) and a tensile strength of 140 ksi (965.3 MPa). These are increased to 76.7 ksi (528.8 MPa) and 144 ksi (993.4 MPa), respectively, at 1598°F (870°C). The alloy also possesses superior elongation of 54% at room and 34% at elevated temperatures (MFG Shop).

Besides its yield and tensile strengths, Inconel 625 retains its mechanical properties in various temperatures, from cryogenic to approximately 1800°F (982°C). It is, therefore, suitable for use in applications requiring resistance against harsh thermal conditions (MFG Shop)

➢ *Thermal Stability*

One of the most notable strengths of the alloy is its ability to maintain its mechanical properties in high-temperature conditions. Inconel 625 can withstand temperatures of 1000°C (1832°F) without compromising tensile strength and structural integrity. This heat resistance is critical when materials experience fluctuating and extreme temperatures in applications like jet engines, exhausts, and hot gas paths (Ronsco Steel).

➢ *Resistance to Thermal Fatigue*

Inconel 625 exhibits exceptional thermal fatigue and cyclic loading resistance, making it reliable in dynamic environments. This property is especially beneficial because components in power generation and aerospace applications are frequently exposed to thermal cycling (MFG Shop).

➢ *Weldability and Fabricability*

The alloy is highly weldable and fabricable. It can be welded using most welding processes without losing mechanical properties. It is difficult to machine and shape because of its high strength and hardness; therefore, special tools and methods must be used (Ronsco Steel).

B. Chemical Properties of Inconel 625

➢ *Chemical Composition*

The chemical composition of Inconel 625 determines its performance. The alloy contains predominantly nickel (58-63%) and chromium (20-23%), as well as insignificant amounts of molybdenum (8-10%) and niobium (3.15-4.15%). Trace components include iron (up to 5%), cobalt (up to 1%), manganese (up to 0.5%), silicon (up to 0.5%), aluminum (up to 0.4%), titanium (up to 0.4%), carbon (up to 0.1%), phosphorus (up to 0.015%), and sulfur (up to 0.015%) (MFG Shop).

The remarkable corrosion resistance, high strength, and thermal stability of Inconel 625 are attributed to this composition. In harsh conditions, the high concentration of nickel and chromium creates a protective oxide layer that inhibits oxidation and corrosion (Lion Alloy).

➢ *Corrosion Resistance*

Inconel 625 is highly resistant to corrosive environments, including oxidizing and reducing conditions. It exhibits good resistance to stress corrosion cracking, pitting, and crevice corrosion. This makes it suitable for application in chemical processing, pollution control systems, and marine atmospheres (Super Metals).

Its corrosive chemical resistance, such as against sulfuric acid, phosphoric acid, and chlorinated solvents, makes the alloy more flexible. It is extensively used equipment that deals with corrosive media, i.e., heat exchangers, reactor vessels, and environmental control systems (Ronsco Steel).

➢ *Oxidation Resistance*

The high chromium content in Inconel 625 enables it to form a stable oxide film, which shields the material from additional oxidation when exposed to high temperatures. This use is critical in high-temperature environments, such as jet engine and exhaust system applications (Wikipedia).

C. Applications of Inconel 625 Based on Its Properties

Because of its distinct physical and chemical characteristics, Inconel 625 can be used in various demanding applications.

- **Aerospace**: Because of its stability at high temperatures and resistance to thermal fatigue, it is utilized in jet engines, exhaust systems, and hot gas pathways.
- **Marine**: Ideal for components exposed to saltwater and marine environments, such as wire ropes, cables, and blades on naval crafts.
- **Nuclear Power**: Utilized in reactor cores, control-rod components, and steam generators due to its corrosion resistance and thermal stability.
- **Chemical Processing**: Commonly employed in heat exchangers, reactor vessels, and pollution control systems where exposure to aggressive chemicals is frequent (Continental Steel).

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D. Challenges and Limitations

While Inconel 625 offers numerous advantages, it also presents some challenges:

- **Machinability**: The alloy's high strength and hardness make it difficult to machine, requiring specialized tools and techniques (Ronsco Steel).
- **Cost**: Due to its complex composition and manufacturing process, Inconel 625 is more expensive than other materials, such as stainless steel.
- **High-Temperature Strength**: Although it performs well at elevated temperatures, it is not as strong as other superalloys, such as Inconel 718, at extreme temperatures (Lion Alloy).

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