

SOONV[®] nickel-copper alloy R-405 (UNS N04405) is the free-machining grade of alloy 400. Its greater sulfur content enhances machinability. It has essentially the same corrosion resistance and physical properties as alloy 400, but a slightly different range of mechanical properties. Alloy R-405 is used chiefly for automatic-screw-machine stock and is not generally recommended for other applications. The composition is shown in Table 1.

Thermal expansion of alloy R-405 is shown in Table 2. The values for physical constants and other thermal properties of SOONV alloy 400 may be used for SOONV alloy R-405 and are shown in Tables 3 and 4.

Table 1 - Limiting Chemical Composition, %, of Soonv Alloy R-405

| | |
|----------------------------|-------------|
| Nickel (plus Cobalt) | 63.0 min. |
| Carbon | 0.3 max. |
| Manganese | 2.0 max. |
| Iron | 2.5 max. |
| Sulfur | 0.025-0.060 |
| Silicon | 0.5 max. |
| Copper | 28.0 - 34.0 |

Table 2 - Thermal Expansion of SOON Alloy R-405

| Temperature, °F | Mean Linear Expansion, ^a in./in./°F x 10 ⁻⁶ |
|-----------------|--|
| 200 | 7.6 |
| 400 | 8.4 |
| 600 | 8.7 |
| 800 | 9.0 |
| 1000 | 9.2 |
| 1200 | 9.4 |
| 1400 | 9.7 |
| 1600 | 9.9 |
| 1700 | 10.0 |
| 1800 | 10.1 |
| 2000 | 10.4 |

^a Between 70°F and temperature shown.

Table 3 - Physical Constants of Soonv Alloy 400 ^a

| | |
|--|-----------|
| Density, g/cm ³ | 8.80 |
| lb/in. ³ | 0.318 |
| Melting Range, °F | 2370-2460 |
| °C | 1300-1350 |
| Modulus of Elasticity, 10 ³ ksi | |
| Tension | 26.0 |
| Compression | 26.0 |
| Torsion | 9.5 |
| Poisson's Ratio | 0.32 |
| Curie Temperature, °F | 70-120 |
| °C | 21-49 |

^a These values also apply to SOON alloy R-405, the free-machining version of SOON alloy 400.

Table 4 - Thermal Properties of Soonv Alloy 400

| Temperature | | Mean Linear Expansion ^b | | Thermal Conductivity ^a | | Specific Heat ^a | | Electrical Resistivity ^{a,c} | |
|-------------|------|------------------------------------|-------------------|-----------------------------------|-------------------|----------------------------|---------|---------------------------------------|-------|
| °F | °C | in/in/°F x 10 ⁻⁶ | µm/m•°C | Btu-in/h/ft ² •°F | W/m•°C | Btu/lb•°F | J/kg•°C | ohm-circ mil/ft | µΩ•m |
| -320 | -200 | - | - | - | - | - | - | 205 | 0.360 |
| -300 | -180 | 6.1 | 11.1 | 113 | 16.5 | 0.050 | 223 | - | - |
| -200 | -130 | 6.4 | 11.4 | 130 | 18.2 | 0.078 | 320 | - | - |
| -100 | -70 | 6.7 | 12.1 | 139 | 19.8 | 0.088 | 378 | - | - |
| 70 | 21 | - | - | 151 | 22.0 | 0.102 | 427 | 307 | 0.511 |
| 200 | 100 | 7.7 | 14.2 | 167 | 24.0 | 0.105 | 445 | 322 | 0.537 |
| 400 | 200 | 8.6 | 15.2 | 193 | 26.9 | 0.110 | 459 | 337 | 0.559 |
| 600 | 300 | 8.8 | 15.7 | 215 | 30.1 | 0.114 | 470 | 346 | 0.574 |
| 800 | 400 | 8.9 | 16.1 | 238 | 33.4 | - | - | 355 | 0.587 |
| 1000 | 500 | 9.1 | 16.3 | 264 | 36.5 | - | - | 367 | 0.603 |
| 1200 | 600 | 9.3 | 16.6 | 287 | 39.4 | - | - | 379 | 0.620 |
| 1400 | 700 | 9.6 | 17.0 | 311 | 42.4 | - | - | 391 | 0.639 |
| 1600 | 800 | 9.8 | 17.4 | 335 ^d | 45.5 ^d | - | - | 403 | 0.658 |
| 1800 | 900 | 10.0 ^d | 17.7 | 360 ^d | 48.8 ^d | - | - | 415 | 0.675 |
| 2000 | 1000 | 10.3 ^d | 18.1 ^d | - | - | - | - | 427 | 0.692 |

^a These values also apply to Soonv alloy R-405, the free-machining version of SOON alloy 400.

^b Annealed material. Between 70°F (21°C) and temperature shown.

^c Annealed material.

^d Extrapolated.

alloy R-405

Mechanical Properties

The ranges of nominal mechanical properties of SOONV alloy R-405 rod and bar are shown in Table 5.

Fatigue strength of alloy R-405 in various conditions is shown in Table 6. Toughness of the material is shown by the impact data in Tables 7, 8 and 9. The tension and torsion data are from Catlin and Mudge. Table 10 gives compressive properties found for the alloy.

Alloy R-405 is approved as a material of construction under Section VIII (Pressure Vessels - Division 1) of the ASME Boiler and Pressure Vessel Code and in Section III, Nuclear Vessels, of the Code.

Table 7 - Impact Strength^a of Soonv Alloy R-405 Rod

| Condition | Impact Strength, ft-lb | |
|------------|------------------------|----------------|
| | Izod | Charpy U Notch |
| Hot-Rolled | 96 | 187 |
| Cold-Drawn | 99 | 140 |
| Annealed | 120+ | 196 |

^a Tested at room temperature. None of the specimens was completely fractured.

Table 5 - Nominal Mechanical Property Ranges of Soonv Alloy R-405 Rod and Bar ^a

| Condition | Tensile Strength, ksi | Yield Strength (0.2% Offset), ksi | Elongation, % | Hardness | |
|----------------------|-----------------------|-----------------------------------|---------------|-------------------|------------|
| | | | | Brinell (3000 kg) | Rockwell B |
| Annealed | 70 - 85 | 25 - 40 | 50 - 35 | 110 - 140 | 60 - 76 |
| Hot-Finished | 75 - 90 | 35 - 60 | 45 - 30 | 130 - 170 | 72 - 86 |
| Cold-Drawn, As-Drawn | 85 - 115 | 50 - 105 | 35 - 15 | 160 - 245 | 85 - 23C |

^a The ranges shown are composites for various product sizes and therefore are not suitable for specification purposes.

Table 6 - Fatigue Strength of Soonv Alloy R-405 Rod ^a

| Condition | Fatigue Strength (10 ⁸ Cycles), ksi | Tensile Strength, ksi | Ratio, Fatigue Strength/Tensile Strength |
|---|--|-----------------------|--|
| Annealed | 30.0 | 75.5 | 0.40 |
| Hot-Rolled | 36.0 | 80.0 | 0.45 |
| Cold-Drawn, As-Drawn | 36.5 | 90.5 | 0.40 |
| Cold-Drawn, Stress-Equalized ^b | 40.0 | 95.0 | 0.42 |

^a Rotating-beam tests of polished specimens in air at room temperature and 10,000 rpm.

^b 525°F/3 hr.

Table 8 - Tension Impact Strength of Soonv Alloy R-405 Rod

| Condition | Tension Impact | | | Tensile Properties | | | | |
|---------------------------------|-------------------------------------|---------------------------|----------------------|-----------------------|-----------------------------------|------------------------|----------------------|-----------------------------|
| | Impact Strength, ^a ft-lb | Elongation in 3.54 in., % | Reduction of Area, % | Tensile Strength, ksi | Yield Strength (0.2% Offset), ksi | Elongation in 2 in., % | Reduction of Area, % | Hardness, Brinell (3000 kg) |
| Cold-Drawn 24%, Stress-Relieved | 90 | 17.0 | 64.7 | 83.15 | 74.35 | 28.0 | 66.6 | 180 |
| Annealed 1450°F/3 hr | 148 | 35.0 | 69.1 | 73.35 | 28.00 | 44.5 | 70.1 | 116 |

^a Specimens completely broken.

Table 9 - Charpy Torsion Impact Strength of Soonv Alloy R-405 Rod

| Temper | Impact Strength | | Angle of Twist, ^a degree | Hardness, Brinell (3000 kg) |
|---------------------------------|-----------------|--------------|--|--------------------------------|
| | ft-lb | ft-lb/sq in. | | |
| Hot-Rolled | 30 | 606 | 100.5 | 121 |
| Cold-Drawn 24%, Stress-Relieved | 34 | 687 | 100.5 | 180 |
| Annealed 1450°F/3 hr | 30 | 606 | 102.0 | 116 |

^a Gage length about 3/16 in.

Table 10 - Compressive Properties of Soonv Alloy R-405 Rod

| Temper | Compression | | Tension | | | |
|-------------------------|--|---|--------------------------|--|---|------------------|
| | Yield Strength (0.01% Offset), ksi | Yield Strength (0.2% Offset), ksi | Tensile Strength, ksi | Yield Strength (0.01% Offset), ksi | Yield Strength (0.2% Offset), ksi | Elongation, % |
| Hot-Rolled | 26.0 | 34.0 | 76.0 | 33.0 | 36.0 | 39.5 |
| Cold-Drawn ^a | 51.0 | 66.0 | 83.0 | 62.0 | 74.0 | 28.0 |
| Annealed ^b | 23.0 | 26.0 | 73.0 | 25.0 | 28.0 | 44.5 |

^a Stress-equalized at 525°F after cold drawing.

^b Cold-drawn + 1450°F/3 hr, F.C.

Working Instructions

SOONV alloy R-405 is fabricated, pickled and heat-treated by the same procedures as for alloy 400. The alloy is not recommended for forging.

Machining

SOONV alloy R-405 was especially developed for good machinability and is recommended for use with automatic screw machines. The nickel-copper sulfides resulting from the sulfur in its composition act as chip breakers. Because of these inclusions the surface finish of the alloy is not as smooth as that of SOONV alloy 400.

Joining

SOONV alloy R-405 may be joined by standard welding, brazing and soldering techniques. In general, processes and procedures are the same as for SOONV alloy 400.

Available Products and Specifications

SOONV alloy R-405 is designated UNS N04405 and is normally furnished only in the form of rod and bar. Standard sizes of these products are available from stock. Wire and specialty products are available from converters.

Applicable specifications are:

Bar and Rod: ASME SB-164, ASTM B-164, Federal QQ-N-281, SAE AMS 4674 & 7234, Military MIL-N-894, NACE MR-01-75.