

## Haynes Hastelloy® C-22HS, Nickel Alloy Gas Tungsten Arc Welded (GTAW) All Weld Cruciform

Category : Metal , Nonferrous Metal , Nickel Alloy

### Material Notes:

Outstanding Corrosion Resistance, High Strength HASTELLOY® C-22HSTM alloy is corrosion-resistant, nickel-chromium-molybdenum alloy which can be heat treated to obtain a strength approximately double that of other C-type alloys. Importantly, the corrosion resistance and ductility of the alloy remain excellent when in the high strength condition. In addition to its high uniform corrosion resistance in oxidizing as well as reducing environments, the as-heat treated C-22HS alloy possesses high resistance to chloride-induced pitting and crevice corrosion attack. C-22HS alloy is available in the form of plate, sheet, strip, billet, bar, wire, pipe, and tube. Heat Treatment: The high strength of C-22HS alloy is derived from the formation of strengthening particles of Ni<sub>2</sub>(Mo,Cr) which form during the patented two-step age-hardening heat treatment. The approximately 48 hour heat treatment, 1300°F (705°C) FC to 1125°F (605°C)/32 hours/AC, is described in more detail on page 14. Solution Annealed and Filler Wire Applications: C-22HS alloy may also be considered for applications which do not require the high strength imparted by the heat treatment. In the annealed condition, C-22HS alloy has even higher corrosion-resistance, particularly with regard to localized corrosive attack. This localized attack resistance also makes the alloy an attractive candidate as a general-purpose filler metal or weld overlay. Applications: Agitators and blenders Shafting Fan blades and hubs Fasteners Springs Valves Dies Screws Wellhead parts Rings and gaskets Heat Treatment: Wrought forms of C-22HS alloy are furnished in the solution annealed condition, unless otherwise specified. The standard solution annealing treatment consists of heating to 1975°F (1080°C) followed by rapid air-cooling or water quenching. Parts which have been hot formed should be solution annealed prior to final fabrication or installation. To use the alloy in the high-strength condition, it is necessary to age-harden using a two step treatment of 1300°F (705°C) for 16 hours, furnace cooling to 1125°F (605°C) and holding at that temperature for 32 hours, followed by an air cool. Cold or hot-worked structures should normally be given a full solution anneal prior to performing the age-hardening treatment. Forming: C-22HS alloy has excellent forming characteristics, and cold forming is the preferred method of shaping. The alloy can be easily cold worked due to its good ductility. The alloy is generally stiffer than the austenitic stainless steels; therefore more energy is required during cold forming. For further information on the fabrication of C-type alloys, please consult publication H-2010. Machining: C-22HS alloy may be machined in either the solution annealed or age-hardened condition. Carbide or ceramic tools are recommended. For use in the age-hardened condition, it is suggested to rough machine in the annealed condition. After performing the age-hardening heat treatment, light machining may be performed to achieve desired final dimensions. Tensile properties reported are for Gas Tungsten Arc welded all-weld-metal specimens from Cruciform. Other properties are typical of the alloy. Data provided by the manufacturer, Haynes International, Inc.

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| Physical Properties | Metric    | English                  | Comments     |
|---------------------|-----------|--------------------------|--------------|
| Density             | 8.60 g/cc | 0.311 lb/in <sup>3</sup> | annealed     |
|                     | 8.64 g/cc | 0.312 lb/in <sup>3</sup> | age-hardened |

| Mechanical Properties      | Metric             | English             | Comments  |
|----------------------------|--------------------|---------------------|-----------|
| Tensile Strength, Ultimate | 708 MPa            | 103000 psi          | As welded |
|                            | @Diameter 12.7 mm, | @Diameter 0.500 in, |           |

| Mechanical Properties   | Temperature 25.0 Â°C<br>Metric             | Temperature 77.0 Â°F<br>English             | Comments                              |
|-------------------------|--------------------------------------------|---------------------------------------------|---------------------------------------|
|                         | 1062 MPa                                   | 154000 psi                                  | Welded then age-hardened              |
|                         | @Diameter 12.7 mm,<br>Temperature 25.0 Â°C | @Diameter 0.500 in,<br>Temperature 77.0 Â°F |                                       |
| Tensile Strength, Yield | 458 MPa                                    | 66400 psi                                   | As welded; 0.2% offset                |
|                         | @Diameter 12.7 mm                          | @Diameter 0.500 in                          |                                       |
|                         | 735 MPa                                    | 107000 psi                                  | Welded then age-hardened; 0.2% offset |
|                         | @Diameter 12.7 mm                          | @Diameter 0.500 in                          |                                       |
| Elongation at Break     | 28.9 %                                     | 28.9 %                                      | Welded then age-hardened              |
|                         | @Diameter 12.7 mm,<br>Temperature 25.0 Â°C | @Diameter 0.500 in,<br>Temperature 77.0 Â°F |                                       |
|                         | 39.2 %                                     | 39.2 %                                      | As welded                             |
|                         | @Diameter 12.7 mm,<br>Temperature 25.0 Â°C | @Diameter 0.500 in,<br>Temperature 77.0 Â°F |                                       |
| Modulus of Elasticity   | 181 GPa                                    | 26300 ksi                                   | Dynamic                               |
|                         | @Temperature 600 Â°C                       | @Temperature 1110<br>Â°F                    |                                       |
|                         | 195 GPa                                    | 28300 ksi                                   | Dynamic                               |
|                         | @Temperature 500 Â°C                       | @Temperature 932 Â°F                        |                                       |
|                         | 205 GPa                                    | 29700 ksi                                   | Dynamic                               |
|                         | @Temperature 400 Â°C                       | @Temperature 752 Â°F                        |                                       |
|                         | 209 GPa                                    | 30300 ksi                                   | Dynamic                               |
|                         | @Temperature 300 Â°C                       | @Temperature 572 Â°F                        |                                       |
|                         | 211 GPa                                    | 30600 ksi                                   | Dynamic                               |
|                         | @Temperature 200 Â°C                       | @Temperature 392 Â°F                        |                                       |
|                         | 218 GPa                                    | 31600 ksi                                   | Dynamic                               |
|                         | @Temperature 100 Â°C                       | @Temperature 212 Â°F                        |                                       |
|                         | 223 GPa                                    | 32300 ksi                                   | Dynamic                               |
|                         | @Temperature 25.0<br>Â°C                   | @Temperature 77.0 Â°F                       |                                       |

| Thermal Properties | Metric                         | English                        | Comments |
|--------------------|--------------------------------|--------------------------------|----------|
| CTE, linear        | 11.6 Âµm/m-Â°C                 | 6.44 Âµin/in-Â°F               |          |
|                    | @Temperature 25.0 -<br>100 Â°C | @Temperature 77.0 -<br>212 Â°F |          |

| Thermal Properties     | Metric $\mu\text{m}/\text{m}\cdot\text{Å}^\circ\text{C}$ | English $\text{in}/\text{in}\cdot\text{Å}^\circ\text{F}$  | Comments |
|------------------------|----------------------------------------------------------|-----------------------------------------------------------|----------|
|                        | @Temperature 25.0 - 200 $\text{Å}^\circ\text{C}$         | @Temperature 77.0 - 392 $\text{Å}^\circ\text{F}$          |          |
|                        | 12.4 $\mu\text{m}/\text{m}\cdot\text{Å}^\circ\text{C}$   | 6.89 $\mu\text{in}/\text{in}\cdot\text{Å}^\circ\text{F}$  |          |
|                        | @Temperature 25.0 - 300 $\text{Å}^\circ\text{C}$         | @Temperature 77.0 - 572 $\text{Å}^\circ\text{F}$          |          |
|                        | 12.7 $\mu\text{m}/\text{m}\cdot\text{Å}^\circ\text{C}$   | 7.06 $\mu\text{in}/\text{in}\cdot\text{Å}^\circ\text{F}$  |          |
|                        | @Temperature 25.0 - 400 $\text{Å}^\circ\text{C}$         | @Temperature 77.0 - 752 $\text{Å}^\circ\text{F}$          |          |
|                        | 13.1 $\mu\text{m}/\text{m}\cdot\text{Å}^\circ\text{C}$   | 7.28 $\mu\text{in}/\text{in}\cdot\text{Å}^\circ\text{F}$  |          |
|                        | @Temperature 25.0 - 500 $\text{Å}^\circ\text{C}$         | @Temperature 77.0 - 932 $\text{Å}^\circ\text{F}$          |          |
|                        | 13.3 $\mu\text{m}/\text{m}\cdot\text{Å}^\circ\text{C}$   | 7.39 $\mu\text{in}/\text{in}\cdot\text{Å}^\circ\text{F}$  |          |
|                        | @Temperature 25.0 - 600 $\text{Å}^\circ\text{C}$         | @Temperature 77.0 - 1110 $\text{Å}^\circ\text{F}$         |          |
| Specific Heat Capacity | 0.412 J/g- $\text{Å}^\circ\text{C}$                      | 0.0985 BTU/lb- $\text{Å}^\circ\text{F}$                   |          |
|                        | @Temperature 25.0 $\text{Å}^\circ\text{C}$               | @Temperature 77.0 $\text{Å}^\circ\text{F}$                |          |
|                        | 0.434 J/g- $\text{Å}^\circ\text{C}$                      | 0.104 BTU/lb- $\text{Å}^\circ\text{F}$                    |          |
|                        | @Temperature 100 $\text{Å}^\circ\text{C}$                | @Temperature 212 $\text{Å}^\circ\text{F}$                 |          |
|                        | 0.451 J/g- $\text{Å}^\circ\text{C}$                      | 0.108 BTU/lb- $\text{Å}^\circ\text{F}$                    |          |
|                        | @Temperature 200 $\text{Å}^\circ\text{C}$                | @Temperature 392 $\text{Å}^\circ\text{F}$                 |          |
|                        | 0.465 J/g- $\text{Å}^\circ\text{C}$                      | 0.111 BTU/lb- $\text{Å}^\circ\text{F}$                    |          |
|                        | @Temperature 300 $\text{Å}^\circ\text{C}$                | @Temperature 572 $\text{Å}^\circ\text{F}$                 |          |
|                        | 0.477 J/g- $\text{Å}^\circ\text{C}$                      | 0.114 BTU/lb- $\text{Å}^\circ\text{F}$                    |          |
|                        | @Temperature 400 $\text{Å}^\circ\text{C}$                | @Temperature 752 $\text{Å}^\circ\text{F}$                 |          |
|                        | 0.488 J/g- $\text{Å}^\circ\text{C}$                      | 0.117 BTU/lb- $\text{Å}^\circ\text{F}$                    |          |
|                        | @Temperature 500 $\text{Å}^\circ\text{C}$                | @Temperature 932 $\text{Å}^\circ\text{F}$                 |          |
|                        | 0.504 J/g- $\text{Å}^\circ\text{C}$                      | 0.120 BTU/lb- $\text{Å}^\circ\text{F}$                    |          |
|                        | @Temperature 600 $\text{Å}^\circ\text{C}$                | @Temperature 1110 $\text{Å}^\circ\text{F}$                |          |
| Thermal Conductivity   | 11.8 W/m-K                                               | 81.9 BTU-in/hr-ft $\text{Å}^2$ - $\text{Å}^\circ\text{F}$ |          |
|                        | @Temperature 25.0 $\text{Å}^\circ\text{C}$               | @Temperature 77.0 $\text{Å}^\circ\text{F}$                |          |
|                        | 13.5 W/m-K                                               | 93.7 BTU-in/hr-ft $\text{Å}^2$ - $\text{Å}^\circ\text{F}$ |          |

| Thermal Properties | Metric@Temperature 100 Â°C | English@ Temperature 212 Â°F | Comments |
|--------------------|----------------------------|------------------------------|----------|
|                    | 15.4 W/m-K                 | 107 BTU-in/hr-ftÂ²-Â°F       |          |
|                    | @Temperature 200 Â°C       | @Temperature 392 Â°F         |          |
|                    | 17.1 W/m-K                 | 119 BTU-in/hr-ftÂ²-Â°F       |          |
|                    | @Temperature 300 Â°C       | @Temperature 572 Â°F         |          |
|                    | 18.6 W/m-K                 | 129 BTU-in/hr-ftÂ²-Â°F       |          |
|                    | @Temperature 400 Â°C       | @Temperature 752 Â°F         |          |
|                    | 20.5 W/m-K                 | 142 BTU-in/hr-ftÂ²-Â°F       |          |
|                    | @Temperature 500 Â°C       | @Temperature 932 Â°F         |          |
|                    | 22.4 W/m-K                 | 155 BTU-in/hr-ftÂ²-Â°F       |          |
|                    | @Temperature 600 Â°C       | @Temperature 1110 Â°F        |          |
| Melting Point      | 1304 - 1368 Â°C            | 2379 - 2494 Â°F              |          |
| Solidus            | 1304 Â°C                   | 2379 Â°F                     |          |
| Liquidus           | 1368 Â°C                   | 2494 Â°F                     |          |

| Component Elements Properties | Metric      | English     | Comments   |
|-------------------------------|-------------|-------------|------------|
| Aluminum, Al                  | <= 0.50 %   | <= 0.50 %   |            |
| Boron, B                      | <= 0.0060 % | <= 0.0060 % |            |
| Carbon, C                     | <= 0.010 %  | <= 0.010 %  |            |
| Chromium, Cr                  | 21 %        | 21 %        |            |
| Cobalt, Co                    | <= 1.0 %    | <= 1.0 %    |            |
| Iron, Fe                      | <= 2.0 %    | <= 2.0 %    |            |
| Manganese, Mn                 | <= 0.80 %   | <= 0.80 %   |            |
| Molybdenum, Mo                | 17 %        | 17 %        |            |
| Nickel, Ni                    | 57 %        | 57 %        | as balance |
| Silicon, Si                   | <= 0.080 %  | <= 0.080 %  |            |
| Tungsten, W                   | <= 1.0 %    | <= 1.0 %    |            |

| Electrical Properties | Metric | English | Comments |
|-----------------------|--------|---------|----------|
|                       |        |         |          |

| Electrical Properties  | 0.0000980 ohm-cm<br>Metric | 0.0000980 ohm-cm<br>English | Comments |
|------------------------|----------------------------|-----------------------------|----------|
| Electrical Resistivity | @Temperature 25.0<br>Â°C   | @Temperature 77.0 Â°F       |          |
|                        | 0.000100 ohm-cm            | 0.000100 ohm-cm             |          |
|                        | @Temperature 100 Â°C       | @Temperature 212 Â°F        |          |
|                        | 0.000104 ohm-cm            | 0.000104 ohm-cm             |          |
|                        | @Temperature 200 Â°C       | @Temperature 392 Â°F        |          |
|                        | 0.000108 ohm-cm            | 0.000108 ohm-cm             |          |
|                        | @Temperature 300 Â°C       | @Temperature 572 Â°F        |          |
|                        | 0.000112 ohm-cm            | 0.000112 ohm-cm             |          |
|                        | @Temperature 400 Â°C       | @Temperature 752 Â°F        |          |
|                        | 0.000115 ohm-cm            | 0.000115 ohm-cm             |          |
|                        | @Temperature 500 Â°C       | @Temperature 932 Â°F        |          |
|                        | 0.000117 ohm-cm            | 0.000117 ohm-cm             |          |
|                        | @Temperature 600 Â°C       | @Temperature 1110<br>Â°F    |          |

| Processing Properties | Metric           | English         | Comments                                      |
|-----------------------|------------------|-----------------|-----------------------------------------------|
| Adapter Temperature   | 607.2 Â°C        | 1125 Â°F        | Step 2, follow by air cooling                 |
|                       | @Time 115000 sec | @Time 32.0 hour |                                               |
|                       | 704 Â°C          | 1300 Â°F        | Step 1; then furnace cool to step 2           |
|                       | @Time 57600 sec  | @Time 16.0 hour |                                               |
| Annealing Temperature | 1079 Â°C         | 1975 Â°F        | Followed by rapid air cooling or water quench |

| Descriptive Properties | Value                     | Comments  |
|------------------------|---------------------------|-----------|
| Thermal Diffusivity    | 0.0334 cm <sup>2</sup> /s | at 25Â°C  |
|                        | 0.0362 cm <sup>2</sup> /s | at 100Â°C |
|                        | 0.0398 cm <sup>2</sup> /s | at 200Â°C |
|                        | 0.0427 cm <sup>2</sup> /s | at 300Â°C |
|                        | 0.0454 cm <sup>2</sup> /s | at 400Â°C |
|                        | 0.0489 cm <sup>2</sup> /s | at 500Â°C |
|                        | 0.0517 cm <sup>2</sup> /s | at 600Â°C |
|                        |                           |           |

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