INCONEL® alloy MA 758 is an oxide-dispersion-strengthened (ODS) nickel-chromium superalloy, made by mechanical alloying. It is a development of the well-established aerospace superalloy, INCONEL alloy MA 754, with its chromium content increased to 30%, to improve its performance in corrosive environments at high temperatures. The alloy's high-temperature strength is enhanced by the use of yttrium oxide for dispersion strengthening.

In addition to its strength and corrosion resistance at high service temperatures, it is readily fabricated and can be hot formed into a range of shaped components for use in thermal processing applications.

INCONEL alloy MA 758 is used in some of the most demanding applications for high-temperature metals and alloys. For example, for furnace skid rails to transport heavy steel billets and slabs, at 1260°C (2300°F) and above, and for the bowl-shaped components used to spin molten glass, at around 1200°C (2200°F), to produce fiberglass for thermal insulation.

It is used in a range of thermal processing applications, from furnace components, such as hearth rollers, to jigs, tools, and other fabrications for supporting workpieces through heat-treatment processes.

It has been specified for a fuel atomizer application in diesel engines.

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**Table 1** - Nominal Composition (wt.%)

| | |
|---|---|
| Chromium | 30.0 |
| Carbon | 0.05 |
| Aluminum | 0.3 |
| Titanium | 0.5 |
| Yttrium oxide ($Y_2O_3$) | 0.6 |
| Iron | 1.0 |
| Nickel | Balance* |

*Reference to the 'balance' of an alloy's composition does not guarantee this is exclusively of the element mentioned, but that it predominates and others are present only in minimal quantities.

## Made by Mechanical Alloying

Mechanical alloying, the process used to produce INCONEL alloy MA 758, is a dry, high-energy ball milling operation that produces composite metal powders with controlled, extremely fine, microstructures.

Typically, a mixture of commercially available metal powders, master alloy powders, and a very fine refractory oxide powder ($Y_2O_3$ for INCONEL alloy MA 758) is charged into the mill.

During the process, metal powder particles are trapped between the rapidly colliding grinding balls and, under the controlled conditions of mechanical alloying, are cold-welded together. The oxide powder particles are trapped within the composite powders along the weld interfaces between the different composite constituents. The cold-welding leads to the build-up of larger powder particles. This is followed by a fracturing stage in which the larger composite powder particles are broken down. A balance is achieved between the welding and the fracturing so that the overall particle size of the composite powder remains nearly constant. The interplay between the welding and fracturing subdivides and kneads the ingredients to create a uniform distribution of the oxide and other metallic components.

Mechanically alloyed powders are consolidated by placing them in sealed cans for extrusion or hot pressing, followed by conventional hot- and cold-working processes. A final anneal at very high temperatures is required to develop the stable, coarse, grain structure suitable for the most demanding stress-rupture applications.

# Physical & Thermal Properties

**Table 2** - General Properties

| | |
|---|---|
| Density, g/cm$^3$ | 8.14 |
| lb/in.$^3$ | 0.294 |
| Melting Point (Solidus), °F | 2507 |
| °C | 1375 |

**Table 3** - High-Temperature Electrical Resistivity

| Temperature | | Electrical Resistivity | |
|---|---|---|---|
| °F | °C | ohm-circ. mil/ft | microhm-cm |
| 71 | 22 | 685.1 | 113.9 |
| 200 | 93 | 692.0 | 115.0 |
| 400 | 204 | 699.5 | 116.3 |
| 600 | 316 | 707.7 | 117.6 |
| 800 | 427 | 714.6 | 118.8 |
| 1000 | 538 | 723.5 | 120.3 |
| 1200 | 649 | 725.5 | 120.6 |
| 1400 | 760 | 721.4 | 119.9 |
| 1600 | 871 | 722.1 | 120.0 |
| 1800 | 982 | 724.2 | 120.4 |
| 2000 | 1093 | 731.7 | 121.6 |
| 2200 | 1204 | 740.6 | 123.1 |

Hot rolled plate, 2400°F (1315°C)/1h/AC, transverse orientation.

**Table 4** - High-Temperature Thermal Expansion Properties

| Temperature | | Linear Expansion | Coefficient of Expansion | |
|---|---|---|---|---|
| °F | °C | in/in x $10^{-3}$ | in/in/°F x $10^{-6}$ | cm/cm/°C x $10^{-6}$ |
| 77 | 25 | 0 | — | — |
| 200 | 92 | 0.85 | 6.93 | 12.47 |
| 300 | 149 | 1.57 | 7.06 | 12.71 |
| 400 | 204 | 2.31 | 7.16 | 12.89 |
| 500 | 260 | 3.10 | 7.32 | 13.18 |
| 600 | 316 | 3.89 | 7.44 | 13.39 |
| 700 | 371 | 4.72 | 7.57 | 13.63 |
| 800 | 427 | 5.58 | 7.72 | 13.90 |
| 900 | 482 | 6.45 | 7.84 | 14.11 |
| 1000 | 538 | 7.30 | 7.91 | 14.24 |
| 1100 | 593 | 8.22 | 8.04 | 14.47 |
| 1200 | 649 | 9.25 | 8.23 | 14.81 |
| 1300 | 704 | 10.10 | 8.26 | 14.87 |
| 1400 | 760 | 11.05 | 8.35 | 15.03 |

Reference temperature, 77°F (25°C)
Expansion testing in accordance with ASTM E228-85.
Hot-rolled plate, 2400°F (1315°C)/1h/AC, transverse orientation.

## Mechanical Properties

The mechanically alloyed ODS superalloys are well known for their exceptionally high strength at high service temperatures. Figure 1 shows the creep strength of INCONEL alloy MA 758 along with two other mechanically alloyed products, INCONEL alloy MA 754 and INCOLOY alloy MA 956, and a typical cast iron-chromium-nickel heat-resisting alloy. At high temperatures, the three superalloys are all significantly stronger than the cast alloy.

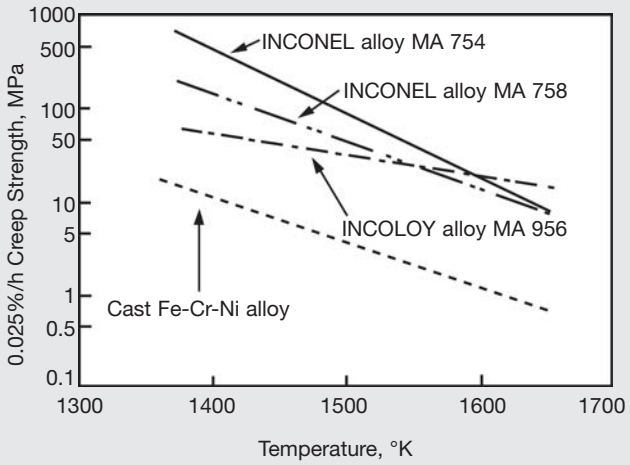


**Figure 1.** Creep strength at high temperatures.

**Table 5** - Mechanical Properties of Bar*

| Temperature | | 0.2% Yield Strength | | Tensile Strength | | Elongation |
|---|---|---|---|---|---|---|
| °C | °F | MPa | ksi | MPa | ksi | % |
| 20 | 68 | 560 | 81.2 | 949 | 137.6 | 27 |
| 200 | 392 | 495 | 71.8 | 853 | 123.7 | 22 |
| 600 | 1112 | 421 | 61.0 | 741 | 107.4 | 23 |
| 700 | 1292 | 371 | 53.8 | 546 | 79.2 | 29 |
| 750 | 1382 | 274 | 39.7 | 429 | 62.2 | 41 |
| 800 | 1472 | 214 | 31.0 | 339 | 49.2 | 47 |
| 1000 | 1832 | 151 | 21.9 | 173 | 25.1 | 29 |

*Extruded round, annealed.

**Table 6** - Mechanical Properties of Plate*

| Temperature | | | 0.2% Yield Strength | | Tensile Strength | | Elongation |
|---|---|---|---|---|---|---|---|
| °F | °C | Direction | ksi | MPa | ksi | MPa | % |
| 68 | 20 | Longitudinal | 98.6 | 680 | 149.4 | 1030 | 14 |
| 68 | 20 | Transverse | 100.0 | 690 | 139.2 | 960 | 22 |
| 1800 | 982 | Longitudinal | 31.9 | 220 | 34.8 | 240 | 4 |
| 1800 | 982 | Transverse | 31.9 | 220 | 36.3 | 250 | 6 |
| 2000 | 1093 | Longitudinal | 24.7 | 170 | 26.1 | 180 | 4 |
| 2000 | 1093 | Transverse | 23.2 | 160 | 27.6 | 190 | 5 |

*9.5 mm (0.375 in) thick, annealed.

# Corrosion Resistance

## Resistance to Oxidation

Because of its high chromium content and the presence of yttrium particles in the matrix, INCONEL alloy MA 758 has outstanding oxidation resistance. Figure 2 shows how the alloy can perform at 1200°C (2200°F) and above for long periods without experiencing severe attack.

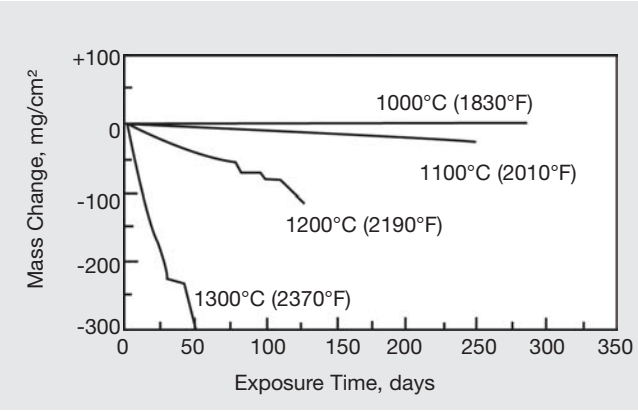


**Figure 2.** Effect of temperature on mass change of INCONEL alloy MA 758 in air.

## Resistance to Molten Glass

Environmental degradation at high temperatures involves the destruction of an alloy's protective scale, followed by penetration by harmful elements; sulfur, oxygen, nitrogen, etc. The exposure of an alloy to molten glass accentuates these problems because of the continuous fluxing of the alloy's protective scale.

INCONEL alloy MA 758 has shown excellent resistance to this type of attack. In a 5-day test at 1200°C (2190°F), the alloy was immersed in a "C" glass (65% $SiO_2$, 8.5% $Na_2O$, 14% CaO, 4% $Al_2O_3$, 5% $B_2O_3$, 3% MgO). It showed only 0.03 mm (0.001 inches) of attack after 5 days in this extremely aggressive environment.

# Fabrication

## Machining

INCONEL alloy MA 758 is readily machined in the fully recrystallized condition (HV 300-350) and has similar machining characteristics to solution-annealed INCONEL alloy 718.

Suggested conditions for single point turning are:

| Depth of Cut | | Carbide Tools | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Brazed | | Throwaway | | Feed | | Tool |
| | | Speed | | Speed | | | | |
| in | mm | ft/min | m/min | ft/min | m/min | in/rev | mm/rev | Material |
| 0.250 | 6.5 | 30-40 | 9-12 | 40-60 | 12-18 | 0.010 | 0.25 | C-2 |
| 0.050 | 1.3 | 40-50 | 12-15 | 50-100 | 15-30 | 0.008 | 0.20 | C-2 |

INCONEL alloy MA 758 can be readily machined using ordinary sulfurized mineral oil. Because of their greater cooling effect, water-based coolants are preferred for use in high speed operations such as turning, milling and grinding. These coolants may be soluble oil or proprietary chemical mixtures.

A soluble oil at a 15:1 dilution or a straight cutting oil of the extreme-pressure (EP), heavy-duty type is suggested. Except for grinding, which depends almost entirely on cooling and flushing, some chemical activity is desired, even in coolants, and is generally provided by chlorine, amines, or other chemicals.

For slower operations like drilling, boring, tapping and broaching, heavy lubricants and very rich mixtures of chemical coolants are desirable. The use of sulfurized oil may cause discoloration of the workpiece and is not recommended for use with cemented carbide tools since the heat generated at the point of the tool may cause the sulfur to attack the binding agent in the carbide.

It is important to remove all lubricants from machined pieces that are to be subjected to high temperatures either in fabrication or in service.

# Fabrication, continued

## Joining

***Fusion Welding***

INCONEL alloy MA 758 is weldable, usually for position welding and other applications that do not call for major stresses in service at the welded joints. In view of the extremely high strength of the alloy, the joints themselves will be of lower strength relative to the base metal. Tensile test results at 2000°F (1095°C) are shown in Table 7. The recommended welding consumable is INCONEL filler metal 52. INCONEL alloy MA 758 may also be joined by brazing.

***Mechanical Fastening***

Bolting, riveting, and other mechanical fastening methods are commonly used for joining INCONEL alloy MA 758 to itself and to other alloys.

***Solid State Joining***

In general, the mechanically alloyed materials are suitable for joining methods that involve solid state diffusion, such as bonding and friction welding.

**Table 7** - Weld Transverse Tensile Tests at 2000°F (1095°C).
Gas-Metal-Arc Welded with INCONEL filler metal 52.

| Post-Weld Heat Treatment | Ultimate Stress | | Yield Stress[a] | | Elongation |
|---|---|---|---|---|---|
| | ksi | MPa | ksi | MPa | % |
| As-welded | 8.6 | 59.3 | 7.8 | 53.8 | 5.5 |
| 2400°F (1315°C)/1h/AC | 10.2 | 70.3 | 10.1 | 69.6 | 7 |
| Base metal longitudinal[b] | 23.2 | 160 | 22.3 | 154 | 8.5 |
| Base metal transverse[b] | 23.6 | 163 | 23.4 | 161 | 6.1 |

[a] Approximate yield strength

[b] Average of 4 tests.

# Available Product Forms

INCONEL alloy MA 758 is available in a range of commercial forms, including tube, plate, round bar and flat bar. Other forms can be made available for development projects of commercial significance.

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