

Technical Data Sheet

UGIPURE® 4441

Chemical analysis (%)

C	Si	Mn	Ni	Cr	Cu	Mo	P	S	N
≤0.030	≤0.75	≤2.0	13.0 – 15.0	17.0 – 19.0	≤0.5	2.5 – 3.0	≤0.025	≤0.010	≤0.1

12-06-2019 – REV 02

General presentation

Grade UGIPURE® 4441 is an implantable austenitic grade that involves consumable electrode remelting. A highly stringent manufacturing process ensures that the structure is extremely clean in terms of inclusion population and extremely homogeneous, with no delta ferrite. In addition, good biocompatibility is ensured. The material obtained is non-magnetic and suitable for MRI scans.

Classification

Austenitic stainless steel.

Designation and Standard

N° Matière		
Europe		USA
DIN 17443	Symbol	UNS
1.4441	X2CrNiMo18-15-3	S31673

- ISO 5832-1 grade D
- ASTM F138

Microstructure

UGIPURE® 4441 is entirely austenitic. It contains no residual ferrite (or delta ferrite). Its non-metallic inclusion content (sulphides and oxides) is very low, which results in the following levels of cleanliness (according to ASTM E45/A or ISO 4967/A).

Inclusion type	Sulphides A	Alumina B	Silicates C	Globular oxides D
Fine	≤ 1.5	≤ 1.5	≤ 1.5	≤ 1.5
Thick	< 1.0	< 1.0	< 1.0	< 1.0

Mechanical properties

Tensile test data

Condition	Temperature T (°C)	Tensile strength Rm (MPa)	Yield strength Rp0.2 (MPa)	Ultimate elongation A (%)	Striction Z (%)
Hypertrempé (Ø≥1.6mm)	20°C	490 - 690	≥ 190	≥ 40	
Ecroui (Ø≥1.6mm)	20°C	860 - 1100	≥ 690	≥ 12	
Tréfilé (Ø<1.6mm)	20°C	860 - 1035		≥ 5	
Extra-dur	20°C	≥ 1400			

Physical properties

Temperature (°C)	Density (kg/dm³)	Elasticity modulus (GPa)	Thermal conductivity (W.m ⁻¹ .K ⁻¹)	Expansion coefficient (between 20°C and T°) (10 ⁻⁶ .K ⁻¹)	Electrical resistivity (μΩ.mm)	Specific heat (J.kg ⁻¹ .K ⁻¹)	Magnetism
20°C	8.0	200	15	-	0.75	500	No
100°C		194		16.0			
200°C		186		16.5			
300°C		179		17.0			
400°C		172		17.5			
500°C		165		18.0			

UGIPURE® 4441 is non-magnetic (no residual ferrite).



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Corrosion resistance

General corrosion

High nickel, chromium and molybdenum contents make UGIPURE® 4441 highly resistant to general corrosion in acid environments.

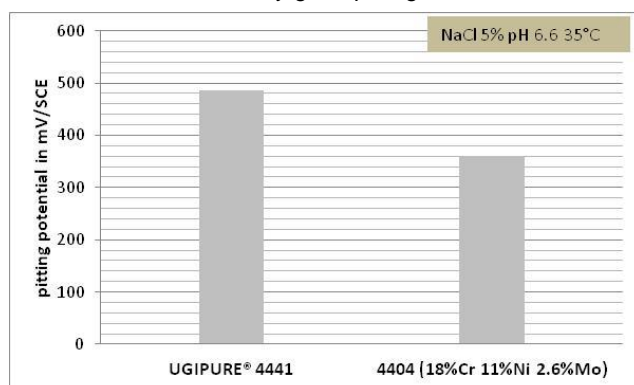
Localised corrosion

— Pitting corrosion

Localised pitting corrosion resistance can be estimated using the Pitting Index formula:

$PREN = \%Cr + 3.3\%Mo + 16\%N$. The PREN calculated from the composition of UGIPURE® 4441 is 27.8, which places it amongst the high PREN values of the molybdenum austenitic family.

The pitting potential was measured electrochemically in the saline environment (5% salt concentration by weight), at neutral pH and 35°C. The figure below compares the pitting potentials of UGIPURE® 4441 and 1.4404 (AISI 316L): UGIPURE® 4441 has very good pitting corrosion resistance.



Intergranular corrosion

— The very low carbon content of UGIPURE® 4441 enables it to meet the requirements of ASTM A262, practice E, and ISO 3651-2 intergranular corrosion tests.



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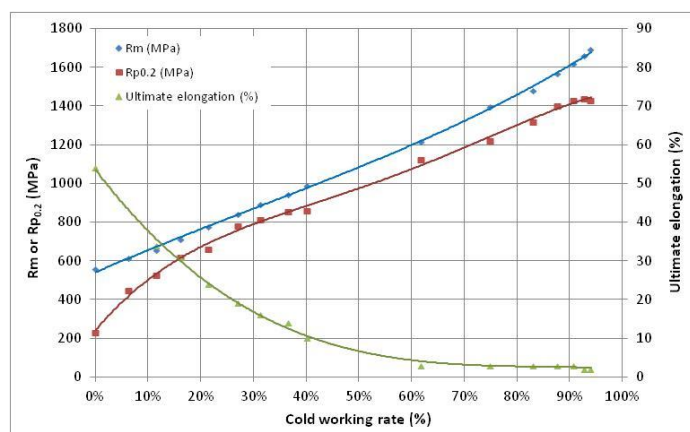
Hot forming

Forging

The grade can be hot formed at between 900°C and 1200°C and then cooled rapidly in water or air. Hot forming is generally followed by solution annealing heat treatment (see recommendations in the relevant section).

Cold forming

UGIPURE® 4441 is highly suitable for cold forming. It has high hardenability compared to non-austenitic grades, which may require specialised tools. The grade remains non-magnetic, even after high cold deformation ratio (no strain-induced martensite formation).



UGIPURE® 4441 cold work-hardening curve

Machinability

Due to its very low inclusion population, UGIPURE® 4441 exhibits poor chip breakability for all cutting operations. That is why the cutting conditions and tool positions should be adjusted whenever possible to minimise the formation of clusters of chips around the tools (see below).

In addition, as for any austenitic grade containing Mo (1.4401, 1.4404, 1.4435 etc.), UGIPURE® 4441 has high mechanical properties and high hardenability likely to increase the cutting forces on the tools and therefore their wear rate, compared to that noted on austenitic stainless steel without Mo, for example

1.4307. The cutting conditions should therefore be adjusted accordingly.

Turning

In terms of tool wear, the absence of an optimised inclusion population for machinability requires cutting conditions to be limited to maintain satisfactory service tool life. This reduction is however quite limited (for example, less than 25 to 30% with respect to a similar grade with improved machinability, such as UGI® 4435 ICH).

The main difficulty with respect to turning is due to UGIPURE® 4441's poor chip breakability. This problem requires the adoption of specific cutting strategies, including:

- an increase in cutting feed rates, whenever possible, (with, at the same time, a reduction in cutting speeds, if they are not already very low) to improve chip breakability;
- downward orientation of tool cutting faces to facilitate chip removal by gravity, in particular for finishing operations where an increase in feed rate is not usually possible;
- generous lubrication with the lubricant jets correctly oriented to mechanically assist the breaking of the long chips generated.

Drilling

During drilling, even more than in turning, UGIPURE® 4441's poor chip breakability requires specific cutting strategies to be adopted. Drills with a central cooling system that encourages chip breaking by the mechanical effect of the pressure of the lubricant at the tool tip and chip removal through the drill flutes are preferred.

In general, if the chips are long and difficult to evacuate through the drill flutes, one or more attempts to clear them will have to be envisaged, depending on the depth of the holes to be drilled. If coated carbide drills are used, attempts should be made to maximise feed rates (while reducing cutting speeds) to try to improve chip breaking.



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If drills with high-speed steel body and coated carbide inserts are used, high cutting speeds and low feed rates may be preferred to minimise cutting forces on the tool, while facilitating chip breaking through the occurrence of vibrations that are often present at high rotational drill speeds.

Welding

Despite a strong tendency to thermal cracking related to its primary austenitic solidification mode, UGIPURE® 4441 can be welded by most processes, thanks to its very low sulphur content.

However, the notion of using it for welded implants is very strongly discouraged.

Heat treatment

Solution annealing treatment ensures optimum corrosion resistance properties. It must be carried out at a temperature between 1050°C and 1120°C and followed by rapid water or air cooling (for small cross section products).

Surface treatment

Pickling

This process is necessary when oxidised surfaces are present during heating. An acid bath must be used: hydrochloric acid, or sulphuric acid, or mixed nitro-hydrofluoric acids. Warming the bath (e.g. to 50°C) reduces immersion time. Finally, it is absolutely essential to rinse the surfaces thoroughly.

Passivation

Stainless steels do not generally need to be passivated: the passive film forms spontaneously in air and, after 24 hours, it achieves a certain stability.

On the other hand, stainless steels can be contaminated by contact with carbon steels or low-alloy steels: this phenomenon is known as ferrous contamination. In this case, nitric acid passivation for 30 minutes at ambient temperature is required. Surface rinsing or even surface neutralisation is essential as a final treatment.

Electropolishing

The usual molybdenum austenitic steel electropolishing conditions can be used for UGIPURE® 4441.



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Available products

Products	Shape	Surface finish	Tolerance	Dimension
Bar	Round	Turned and polished	9 to 11	Ø 22 to 130 mm
		Ground	7 to 9	Ø 1.8 to 80 mm
		Drawn	9	Ø 1.8 to 55 mm
Wire rod	Round	Pickled		Ø 5 to 32 mm
Billett	Square			Ø 50 to 120 mm

Other possibilities on request.

Application

UGIPURE® 4441 can be used to manufacture any surgical implant designed to remain for a long period of time or permanently in the human body:

- prosthesis,
- screw,
- plate,
- etc.



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