# Technical notice
# UGI® 4521 - UGI® 444

**Chemical analysis (%)**

| C | If | Mn | Ni | Cr | Mo | P | S | N | Nb | TI | Nb + Ti |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ≤ 0.025 | ≤ 1.0 | ≤ 1.0 | - | 17.5 - 19.5 | 1.8 - 2.5 | ≤ 0.040 | ≤ 0.015 | ≤ 0.03 | ≥ 0.20 | ≥ 0.08 | 0.2 + 4x(C+N) - 0.8 |

01-08-2022 - REV 01

## General presentation

UGI® 4521 / UGI® 444 is a ferritic stainless steel enriched with molybdenum and further stabilized with niobium and titanium. This grade has a corrosion resistance similar to the austenitic molybdenum steels of the 1.4404 / 316L family while being less expensive due to its low nickel content. With good stress corrosion resistance in a chloride environment and good mechanical properties even at high temperatures, UGI® 4521 is particularly recommended for applications related to the management of drinking water or charged water and applications under pressure and at high temperatures (boilers, heat exchangers, solar panels, etc.). Its service temperature can rise to 850°C in air and go up to 600°C in the presence of water or sulphur compounds .

## Classification

Bi-stabilized niobium and titanium ferritic molybdenum steel.

## Designation

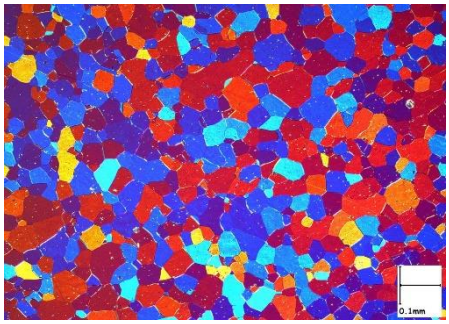
**Material No.**

| Europe - EN | | USA - UNS AISI | | Japan - JIS | World - ISO |
|---|---|---|---|---|---|
| 1.4521 | X2CrMoTi18-2 | S44400 | 444 | SUS444 | 4421-444-00-I |

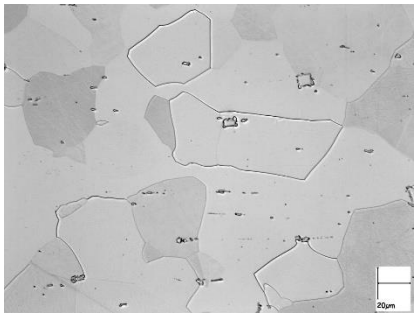
**Standards**

| | |
|---|---|
| **EN** | EN 10088-3 |
| **ASTM** | ASTM A276 - ASTM A959 - ASTM A479 |

## Microstructure




Optical micrograph of a Ø 5.5mm wire rod in UGI® 4521 in cross section.




High magnification optical micrograph of a Ø 5.5mm wire rod in UGI® 4521 in cross section, revealed by Vilella etching, showing precipitation.

Ugitech SA
Avenue Paul Girod
CS90100
73403 UGINE Cedex
www.ugitech.com



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## Mechanical properties

Tensile data on turned bars.

| Temperature | Tensile strength | Yield strength (0,2%) | Elongation | Reduction of area |
|---|---|---|---|---|
| (°C) | (MPa) | (MPa) | (%) | (%) |
| 20 | 450 - 600 | ≥ 300 | ≥ 28 | ≥ 55 |

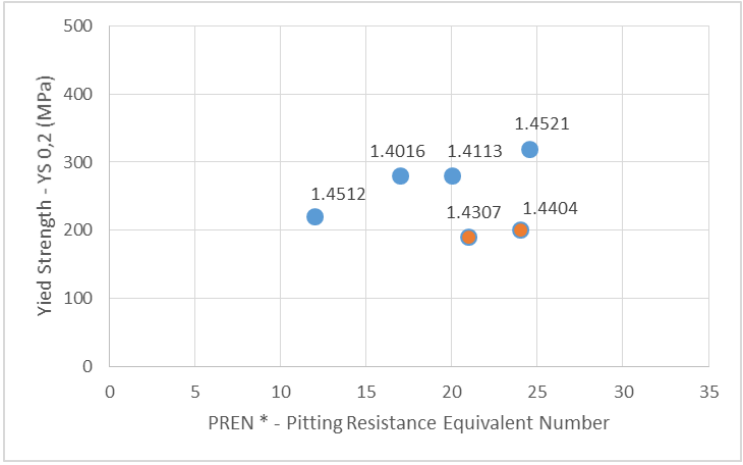
*indicative data*

## Physical properties

| Temperature | Density | Modulus of elasticity | Thermal conductivity | Coefficient of expansion (between 20°C and T°) | Electrical resistivity | Specific heat |
|---|---|---|---|---|---|---|
| (°C) | (kg/dm$^3$ ) | (GPa) | (W/m.°C) | ($10^{-6}$ /°C) | (µΩ.mm) | (J/kg.K) |
| 20 | 7.7 | 215 | 23 | | 800 | 460 |
| 100 | | | 24.8 | 10.4 | | |
| 200 | | | 27.3 | 10.8 | | |
| 300 | | | 29.5 | 11.2 | | |
| 400 | | | 31,0 | 11.6 | | |
| 500 | | | 32,0 | 11.9 | | |

## Resistance to corrosion

UGI® 4521 has a good resistance to all types of corrosion thanks to its chromium and molybdenum content and its bi-stabilization of niobium and titanium. Its PREN* (Pitting Resistance Equivalent Number) of 24,5 predicts a good resistance to pitting corrosion, among the best of all ferritic grades and above that of classic austenitic grades such as 304L/1.4307 and 316L/1.4404 while having better mechanical properties, at least in terms of yield strength (see graph below).




** PREN = %Cr + 3.3%Mo + 16%N*

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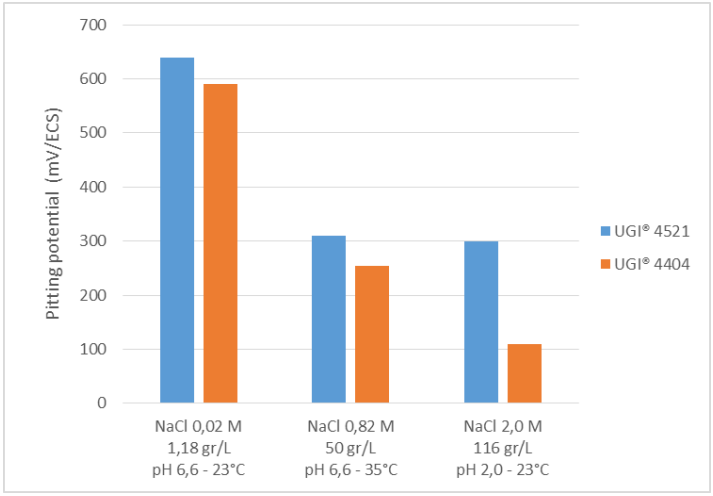
## Pitting corrosion

Regardless of the temperature conditions from 23°C to 35°C and environments ranging from drinking water to brines more concentrated than seawater, the pitting resistance of UGI® 4521 is better than that of type 316L/1.4404 and especially UGI® 4404. As shown in the graph below, the pitting potential of UGI® 4521 is higher than that of IGU® 4404 over a wide range of chloride concentrations.




## Cavernous corrosion

It is known that this type of corrosion can be a weak point of ferritic grades: due to its composition, UGI® 4521 has a resistance equivalent to that of UGI® 4404 in most applications.

For situations considered critical with regard to crevice corrosion (parts with complex geometry presenting confined retention zones), please consult us.

## Intergranular corrosion

UGI® 4521 resists well to intergranular corrosion (standard test specific to ferritic grades ASTM A763-14 ), due to the precipitation of carbon and nitrogen with the niobium and titanium voluntarily added in the grade which avoids the phenomenon of sensitization at the grain boundaries.

## Stress corrosion

Insensitive to stress corrosion due to its ferritic structure, UGI® 4521 is therefore suitable for use under pressure even in chlorine environments urea, whereas it is known that this mode of corrosion can be a weak point of certain austenitic grades.

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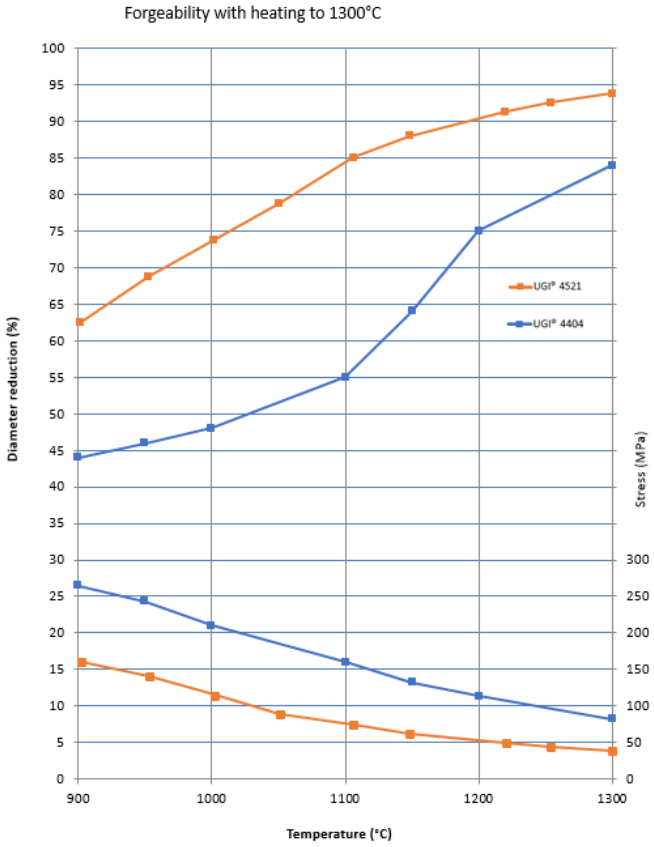
## Hot processing

UGI® 4521 has good forgeability due to its ferritic structure at any temperature. It can be hot formed by forging or rolling between 800°C and 1250°C. It is preferable not to heat above 1150°C to avoid excessive grain size (see forgeability curve below).




## Cold processing

UGI® 4521 has good cold forming properties by bending, drawing or stretching. Due to the presence of molybdenum in the chemical composition, its mechanical properties are similar to the basic autenitics 1.4307 and 1.4404. Its yield strength is even better than that of UGI® 4404 in the unhardened condition.

## Machinability

UGI® 4521 is easier to machine than all other ferritic grades due to the combined presence of molybdenum which hardens the grade, and precipitates of niobium and titanium which together facilitate chip breaking unlike other ferritic grades which often form long chips. A slight addition of sulfur in the grade between 0.005% and 0.015% of sulfur also improves the fragmentation of the chips of UGI® 4521.

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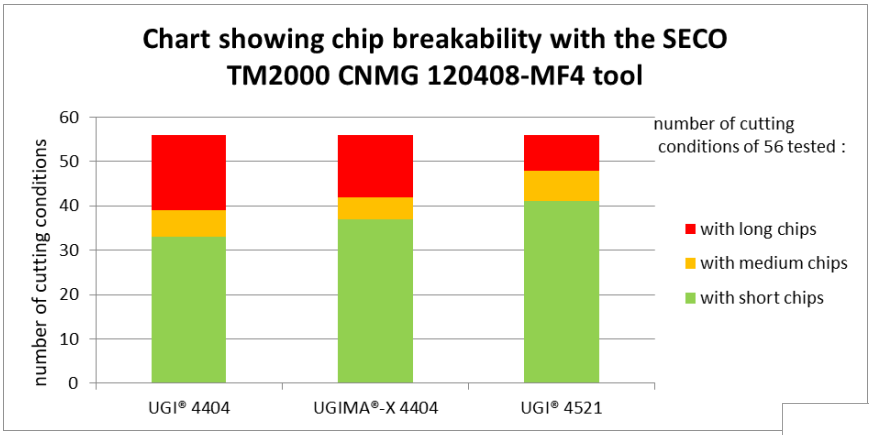
– Chip splitting areas:

In terms of chip splitting (ZFC tests, representative of the metal's ability to limit machine stoppages due to chip entanglement around tools), UGI® 4521 has a greater number of short chip cutting conditions than austenitic grades of type 316L/1.4404 including one with improved machinability such as UGIMA®-X 4404.

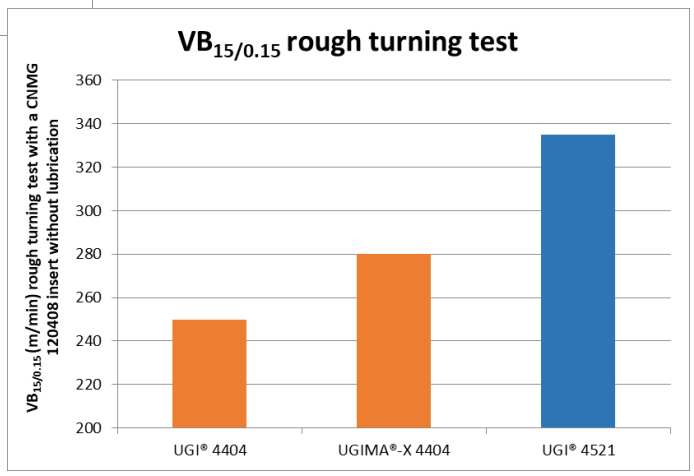
This is shown in the graphs below where the number of machining conditions generating short, intermediate and long chips (among the conditions tested*) are indicated for a reference turning insert and for each grade of stainless steel tested.




* the conditions tested are as follows: at a constant cutting speed (200m/min), the feed rate "f" is varied by 0.1 to 0.4 mm/rev, in steps of 0.05 mm/rev, and the depth of cut "$a_p$ " from 0.5 to 4 mm in steps of 0.5 mm 0.5 mm; 56 cutting conditions are thus tested

Rough turning

In terms of insert wear ($VB_{15/0,15}$ tests are representative of potential rough turning productivity), the UGI® 4521 has cutting conditions above 300 m/min, which places it above a standard 1.4404 (UGI® 4404) and its enhanced machinability version, the UGIMA® -X 4404.




Nevertheless, as with all ferritic grades, UGI® 4521 occasionally presents risks of chip sticking at the cutting tool tip. In order to take full advantage of the potential of this grade, taking into account your working environment and your workpieces, we invite you to contact our Customer Technical Support Department: machinig.support@ugitech.com

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## Surface treatment

A slight change in surface coloration may occur as a result of a welding operation. This discoloration can be removed by mechanical or chemical pickling. Chemical pickling can be done with fluoronitric solution (10% $HNO_3$ + 2% HF). This treatment can be followed by a depassivation operation by immersion in a cold nitric bath at 20-25°C.

## Welding

Thanks to its bi-stabilization with niobium and titanium, UGI® 4521 can be welded by most arc welding processes (MIG/TIG, with or without filler metal, coated electrodes, plasma...), by laser, by resistance (spot or roller), by friction or by electron beam...

No heat treatment should be performed before or after welding to avoid coarsening the ferritic grain of the grade.

When using a welding filler, a homogeneous filler (stabilized ferritic) such as EXHAUST® F1 (18LNb) is preferred in order to guarantee a 100% ferritic homogeneous structure for the welded zone (Molten Zone [MZ] and Thermally Affected Zone [TAZ]); in the case of thick welds (≥ 3mm), an austenitic filler such as ER308L(Si) (1.4316) in order to eliminate the risk of embrittlement of the ZF by excessive grain size.

In MIG, as in TIG, the shielding gas must not contain hydrogen or nitrogen. In MIG, welding is carried out under Ar (+ possibly He) + 1 to 3% $O_2$ or $CO_2$ . In TIG, welding is carried out under Ar (+ possibly He).

## Thermal Treatment - Softening

To restore ductility after cold forming, UGI® 4521 can be treated at a temperature between 750 and 900°C and cooled in air.

## Available products

| Product | Form | Finish | Tolerance | Dimensions (mm) |
|---|---|---|---|---|
| Bars | Rounds | Laminated decalaminated | k13 - k12 | ∅ 22 to 76 mm |
| | | Tours | 10 + 11 | ∅ 22 to 76 mm |
| | | Rectified | 7+8+9+options | ∅ 2 to 76 mm |
| | | Stretched | 9 | ∅ 2 to 30 mm |
| | | Black | ± 1% of ∅ | ∅ 23 to 77 mm |
| Wire rod | Round | Stripped | | ∅ 5.5 to 32 mm |

Others, consult us

## Applications

- Fluid management
- Food industry
- Hot water tanks
- Boilers and heat exchangers
- Heat transfer fluid management

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