

# UGIMA<sup>®</sup> 4005

| Chemical analysis<br>(weight %) | C           | Si    | Mn    | Cr          | Mo    | P       | S           |
|---------------------------------|-------------|-------|-------|-------------|-------|---------|-------------|
|                                 | 0,06 – 0,15 | ≤ 1,0 | ≤ 1,5 | 12,0 – 14,0 | ≤ 0,6 | ≤ 0,040 | 0,15 - 0,35 |

10-01-2013 – REV00

**General overview** UGIMA<sup>®</sup> 4005 is a martensitic stainless steel containing 12 to 14% chromium with a machinability improvement of 15 to 30% thanks to the UGIMA<sup>®</sup> process which enables its oxide inclusions to be controlled.

UGIMA<sup>®</sup> 4005 keeps its other properties as standard UGI 4005 (cold working, weldability, corrosion resistance, ...)

**Classification** Martensitic stainless steel

## Designation

| Material No.       |            |      |        | ISO (ISO15510)            |
|--------------------|------------|------|--------|---------------------------|
| Europe             | USA        |      | Japon  |                           |
| EN                 | ASTM       | AISI | JIS    |                           |
| 1.4005<br>X12CrS13 | UNS S41600 | 416  | SUS416 | 4005-416-00-I<br>X12CrS13 |

UGIMA<sup>®</sup>4005 is in accordance with the following standards :

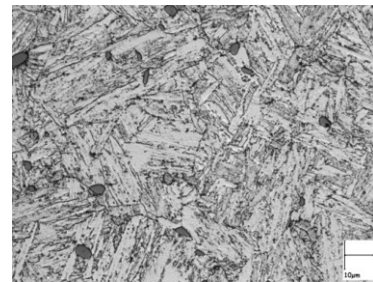
- EN 10088-3 : 2005
- ASTM A959 : 2009

**Microstructure** UGIMA<sup>®</sup> 4005 is delivered preferentially in the QT650 treated condition in order to optimise its machinability. Therefore, its microstructure is a tempered martensite with numerous sulphides, elongated in the direction of the hot rolling.

Microstructure of UGIMA<sup>®</sup> 4005



Longitudinal micrograph



Transverse micrograph

## Mechanical properties

### Tensile and hardness data

| Condition  | Temperature | Tensile strength | Yield strength | Ultimate elongation | Brinell hardness |
|--|-------------|------------------|----------------|---------------------|------------------|
|  | T           | UTS              | 0.2% offset YS | A                   | (HB)             |
|  | (°C)        | (MPa)            | (MPa)          | (%)                 |                  |
| QT650 not work-hardened by drawing                           | 20          | 650 à 850        | ≥ 450          | ≥ 12                | -                |
| QT650 work-hardened by drawing $\varnothing \geq 16$ mm      | 20          | 650 à 930        | ≥ 450          | ≥ 10                | < 250            |
| QT650 work-hardened by drawing $10 < \varnothing \leq 16$ mm | 20          | 700 à 1000       | ≥ 500          | ≥ 8                 | < 280            |
| QT650 work-hardened by drawing $\varnothing \leq 10$ mm      | 20          | 700 à 1000       | ≥ 550          | ≥ 8                 | < 280            |

## Physical properties

| Temperature | Density                | Elasticity modulus | Thermal conductivity                  | Expansion coefficient                | Electrical resistivity | Specific heat                          |
|-------------|------------------------|--------------------|---------------------------------------|--------------------------------------|------------------------|--|
| (°C)        | (kg.dm <sup>-3</sup> ) | (GPa)              | (W.m <sup>-1</sup> .K <sup>-1</sup> ) | (10 <sup>-6</sup> .K <sup>-1</sup> ) | (μΩ.mm)                | (J.kg <sup>-1</sup> .K <sup>-1</sup> ) |
| 20          | 7,7                    | 215                | 30                                    | -                                    | 600                    | 460                                    |
| 100         |                        | 212                |                                       | 10,5                                 |                        |  |
| 200         |                        | 205                |                                       | 11,0                                 |                        |  |
| 300         |                        | 200                |                                       | 11,5                                 |                        |  |
| 400         |                        | 190                |                                       | 12,0                                 |                        |  |



# UGIMA<sup>®</sup> 4005

| Chemical analysis<br>(weight %) | C           | Si    | Mn    | Cr          | Mo    | P       | S           |
|---------------------------------|-------------|-------|-------|-------------|-------|---------|-------------|
|                                 | 0.06 - 0.15 | ≤ 1.0 | ≤ 1,5 | 12.0 - 14.0 | ≤ 0.6 | ≤ 0.040 | 0,15 - 0,35 |

10-01-2013 – REV00

**Corrosion resistance** Corrosion resistance properties of UGIMA<sup>®</sup> 4005 are globally the same as those of a standard UGI 4005. Therefore, storage in an area with low humidity is to be preferred.

## Localised corrosion

### Pitting corrosion

The following figure shows the pitting potential expressed in mV/SCE; it is measured in a saline environment with a pH of 6.6 at 23°C and a sodium chloride concentration of 0.002M (116 mg/l, i.e. 0.01%). This kind of measurement on resulphurised low chromium stainless steel is always highly dispersed and UGIMA<sup>®</sup> 4005 shows, in this test, dispersion slightly over that of a standard UGI 4005.



## Hot working

### Forging

UGIMA<sup>®</sup> 4005 can be forged but it is not suited to severe upsetting operations. The following forging conditions are recommended:

- Heating temperature between 1150°C and 1220°C
- Forging temperature between 950°C and 1220°C
- Slow cooling rate after forging (furnace or vermiculite)

## Machinability

Thanks to its controlled oxide inclusions, UGIMA<sup>®</sup> 4005 presents an excellent machinability, significantly over that of a standard 1.4005 like UGI 4005. For identical cutting conditions, UGIMA<sup>®</sup> 4005 allows tool wear rates far below that of observed when cutting a standard 1.4005.

It allows significant productivity increases without decreasing the tool life duration. As examples, the following table shows for two different cutting tools the  $VB_{15/0,15}$  \* measured in turning on UGIMA<sup>®</sup> 4005 and UGI 4005 hot rolled bars comparatively.

| Grade                   | $VB_{15/0,15}$ in turning (without lubricant) |                                   |
|-------------------------|---|-----------------------------------|
|                         | SECO TM2000<br>CNMG 120408-MF4                | SUMITOMO AC610M<br>CNMG 120408-GU |
| UGI 4005                | 340 m/min                                     | 380 m/min                         |
| UGIMA <sup>®</sup> 4005 | ≥ 490 m/min                                   | ≥ 510 m/min                       |

\*  $VB_{15/0,15}$ : cutting speed inducing a tool flank wear of 0,15mm in 15 min of effective cutting for a depth of cut of 1,5 mm and a feed rate of 0,25 mm/rev (see standard NF ISO 3685).

## Welding

As a standard 1.4005 like UGI 4005, UGIMA<sup>®</sup> 4005 is weldable by most arc welding processes (GMAW, GTAW with or without filler wire, SMAW, SAW, ...), by laser, resistance welding (spot or seam welding), friction or electron beam welding processes, ...

Thanks to a “as welded” martensitic structure in Welded metal (WM) as well as in Heat Affected Zone (HAZ) [if welding without filler wire], UGIMA<sup>®</sup> 4005, as well as a standard 1.4005, is not subject to intergranular corrosion phenomenon due to chromium carbide precipitation and grain boundary déchromisation.

In GMAW and GTAW, the protection gas must be without nitrogen, nor hydrogen, in order to avoid an increasing risk of hydrogen embrittlement typical of martensitic grades. For the same reason, in SMAW, the electrodes



# UGIMA<sup>®</sup> 4005

| Chemical analysis<br>(weight %) | C           | Si    | Mn    | Cr          | Mo    | P       | S           |
|---------------------------------|-------------|-------|-------|-------------|-------|---------|-------------|
|                                 | 0.06 - 0.15 | ≤ 1.0 | ≤ 1,5 | 12.0 - 14.0 | ≤ 0.6 | ≤ 0.040 | 0,15 - 0,35 |

10-01-2013 – REV00

must be oven-dried (in order to eliminate the residual water present in the coating of electrodes, which can increase the hydrogen content in the weld).

Because of its quite low carbon content, UGIMA<sup>®</sup> 4005 can be arc welded without pre-heating of parts to be welded. However, a tempering treatment between 200 and 300°C is needed most of the time to improve the toughness of the HAZ (and that of WM in case of welding without filler wire or with a homogeneous filler wire). With a homogeneous filler wire, heat treatments between 300 and 550°C are prohibited in order to avoid a fine carbide precipitation inducing embrittlement of the HAZ and WM.

In case of austenitic filler wire (309L, 308L, ...), a heat treatment between 200 and 300°C can also be used to improve the HAZ toughness. Heat treatments at higher temperature are prohibited in order to avoid risks of C migration from HAZ into the WM, which could induce corrosion resistance decrease of the WM.

## Heat treatment

### Annealing

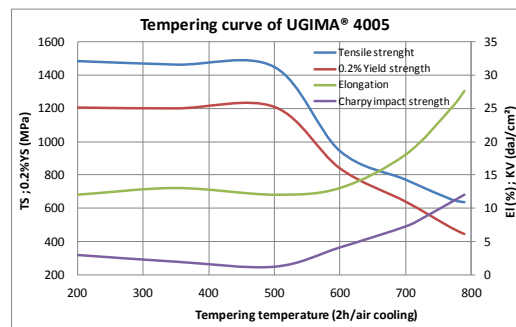
To lower the mechanical properties of UGIMA<sup>®</sup> 4005, make a heat treatment of several hours between 745 and 825°C followed by a slow air cooling.

### Quenching

To quench UGIMA<sup>®</sup> 4005, make a heat treatment between 950°C and 1000°C followed by air or oil cooling.

### Tempering

The choice for the tempering temperature depends on the mechanical properties needed (see the graph hereunder). It is better to avoid temperatures between 400 and 550°C which induce a toughness decrease.



## Surface treatment

The possible surface treatments are the same as those used for a standard 1.4005 such as UGI4005.

## Available products

| Product | Shape    | Finishing                         | Tolerance       | Dimensions (mm)                         |
|---------|----------|-----------------------------------|-----------------|---|
| Bars    | Round    | Hot rolled – Descaled bars        | k13             | 22-77 (every mm)<br>80-115 (every 5 mm) |
|         |          | Cold finished – turned            | h11 - h10       | 22-115                                  |
|         |          | Cold finished – turned & polished | h11 - h10<br>h9 | 22-115<br>22-55                         |
|         |          | Ground bars                       | h9 - h8 - h7    | 22-115                                  |
|         | Hexagone | Cold finished – drawn             | h9              | 5-30                                    |
|         |          | Cold finished - drawn             | h11             | 3-55                                    |

Other finishes, tolerances, sizes, profiles on request

## Applications

Grade used in numerous applications where high machinability is necessary (i.e. for screw machining of very high number of parts), and when corrosion resistance is not a critical deciding factor.

- Process industry : connectors, fixing
- Automotive industry : injectors

This grade can also be used for its magnetic properties in its annealed condition (solenoid valves).

Avenue Paul Girod  
73403 UGINE Cedex - France  
www.ugitech.com

UGITECH

Providing special steel solutions

